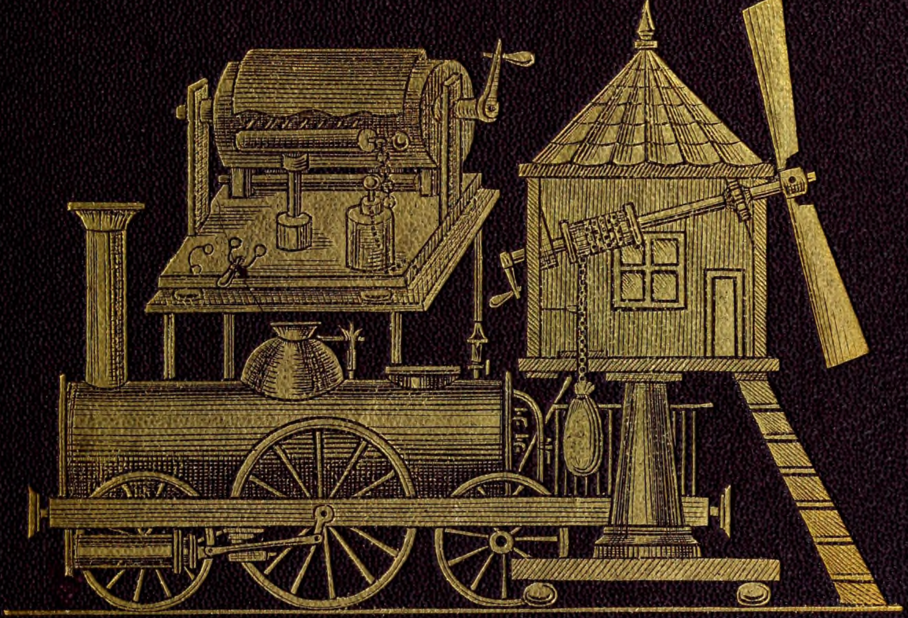
Toy Making



For Amateurs.

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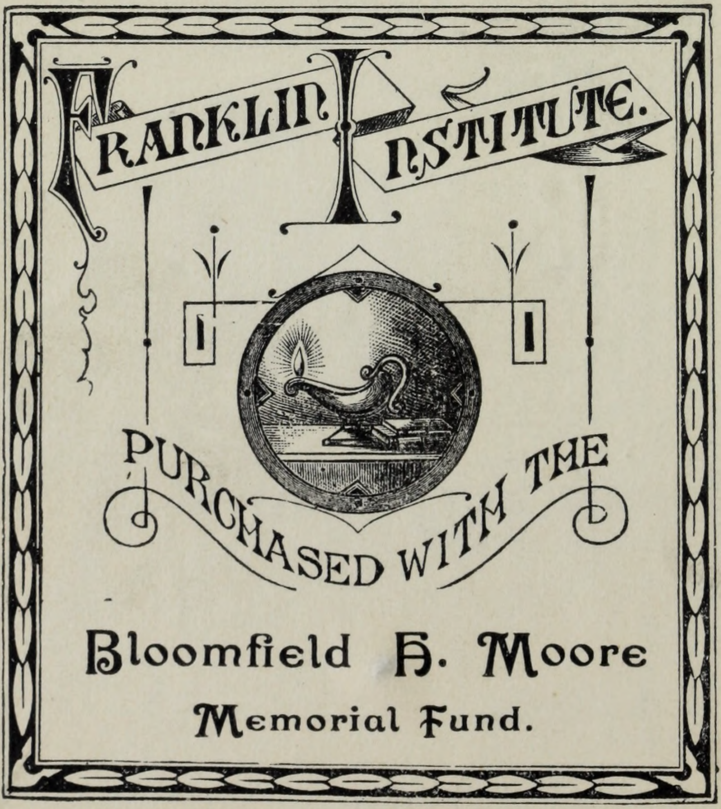

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Toy Making for Amateurs:

BEING

INSTRUCTIONS FOR THE HOME CONSTRUCTION OF
SIMPLE WOODEN TOYS, AND OF OTHERS THAT
ARE MOVED OR DRIVEN BY WEIGHTS,
CLOCKWORK, STEAM, ELECTRICITY, &c.

ILLUSTRATED.

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"WORKING IN SHEET METAL," &c.)

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PREFACE.

THE art of Toymaking may be said to be as old as humanity. If Adam and Eve were, by the peculiarity of their adult condition, debarred from childish recreations, it may fairly be concluded that Cain and Abel initiated youthful games, and made toys of the sticks and stones, or even priceless jewels that met their view, and which, no doubt, suggested ideas handed down to the present race of babies and children. Astride upon a fallen bough, no doubt the wooden horse was simulated as it is in the present day by the early races of juvenile equestrians, and most probably mud pies and other luxuries were not unknown to the pristine families of inventive juveniles. At any rate, toys are to infant minds more sought after than books, and mud pies are appreciated as being better than none. But if we need toys to delight the youngsters, we must have toymakers, and the choice is given us of those much-to-be-dreaded toyshops and the home manufactory. Being mechanically inclined, and having a wholesome dread of those aforenamed toyshops, where every youngster wants everything, and whence he emerges more dissatisfied than he was before, we have endeavoured to teach the art of toymaking, so that youthful hands and minds may be engaged, and gather that satisfaction from their toys which can only be attained by actually making them. Moreover, we regard toymaking as an excellent introduction to the mechanical arts generally, and have therefore not been content to describe the simpler toys, but have advanced, in the latter part of the volume, to those which are of a scientific and practically useful character.

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Toymaking for Amateurs.

INTRODUCTION.

As long as there are children to be amused, so long must we provide entertainment for them, and so long will toys exist and toy shops flourish. But though not extremely aged, I am old enough to be able to draw invidious comparisons between the toys of my childhood and those provided for the young of the present generation, and in few articles has such an astonishing improvement been made. Talk of the march of intellect—the march of toydom beats it hollow! I do not believe a modern baby would look at such rude creations as delighted the babies of fifty years ago. How well I remember the approved type of doll, with its meaningless stare, its illshaped body, and flat lath-like arms and legs. Or if we were, by some rare chance, the happy possessors of a doll of wax—only allowed to be fondled on state occasions—there were still the expressionless features, the staring eyes, set in two shapeless clefts that did duty for eyelids, and generally uninteresting character, which, happily, we were unable to criticise. Look at the doll of the period, even the cheaper sample, with its nicely formed features and pleasing expression of countenance—many of them absolutely pretty and almost intelligent looking.

And if we pass from dolls, and such like, to the really instructive and highly interesting toys of our time—the scientific and mechanical ones—we simply arrive at a class utterly unknown in olden days. These, indeed, pass in an almost unbroken line from the mere toy to the really useful article like the 1s. 6d. or 2s. clocks now so largely imported from Switzerland and elsewhere, the drawing frame for sketching from nature, the shilling pentagraph, and other graphs and contrivances which children of any age may use as a means of recreation or otherwise.

Slightly removed from the genus toy, we arrive at the fret saw, which youngsters, say, of twelve years, or even less, may easily use, after a little careful instruction, and which is a very serviceable addition to the box of tools. This box, like other such articles, has advanced materially in quality, and is not the utterly useless affair it used to be (unless we foolishly expect for 6d. what no one can make at double the price). But in very many cases, especially with a few simple and inexpensive tools, we can make toys at home ; and home work of this kind offers this advantage, that it interests those for whom we are working, and therefore renders a double service. The work of construction interests, and the result still remains a source of pleasure and satisfaction. This I have proved many a time and often, and day by day have I been watched by one or more patient and expectant youngster, as some much desired toy has gradually assumed the well known form, and slowly progressed towards completion. I have never found the interest slacken, and have purposely worked with the utmost deliberation to make the work last the longer. An observant child, too, of even four years, will criticise each article very keenly, looking for some salient detail which it has learnt to regard as an essential part of the toy, a criticism it is always safe to indulge and wise to foster. In a wooden engine, for instance, while a child of three years may be content with a cylindrical body mounted on four wheels, with a chimney at one end, a boy of four, who has probably had opportunities of seeing a real engine, will be looking for the dome on the boiler, or the cylinders at the sides, or tender behind, and after a while he will expect to see a moving piston-rod, or some indication of mechanical action while dragging along the helpless machine of which, as yet, he is content to be the source of motion. A few years more, and the child ceases to regard this type with satisfaction. The incongruity of an engine which needs to be dragged along by its owner strikes him forcibly, and he begins to pine for the working model—clockwork first, perhaps, but subsequently the real thing—an engine worked by steam.

Now, we can buy toys of the make-believe kind or otherwise at a cheap enough rate, but we can construct them nearly or quite as well, with the advantageous results already spoken of. If we confine our labours to the make-believe class, such as wooden engines, we shall find work of real interest to ourselves as well as to the small fry who are ultimately to become the possessors of our handiwork ; if we go further, and aim at something higher and more real, that interest will increase, and in these days of amateur handicraft we shall here discover new and varied subjects for home work and home invention.

Toy-making in a humble way is by no means uncommon among the poorer classes, and by the aid of a pocket knife, not of the sharpest, and a few simple materials, cottagers' children often supply themselves with tops and kites, carts and barrows, which, rude as they may be, bear hard knocks and rough usage a deal better than the more finished productions of the toy shop. I have, indeed, now and then substituted a properly-turned pegtop of "own manufacture" for the less elegant article, and have found it treasured far more than if I had purchased and presented it; and those readers not blessed with youngsters of their own have plenty of scope among the children of the poor for similar acts of thoughtful kindness, which will be appreciated to an extent they would hardly believe. Toys, except in the most limited degree, are, in fact, unknown luxuries in the cottage.

In a manual devoted to toys and toymaking, I feel that some classification is necessary, and one or two plans appear to offer themselves for consideration. I might divide them into wooden and metal toys, and this arrangement presents some advantage, as a different class of tools is needed for each. Or I might draw the line between simple make-believe toys and those working by clockwork, steam, or other power. But the actual division is more difficult to define than at once appears. In the first place many toys are made with advantage of wood and metal in combination, and although of these a good many only need thin metal cut out and attached without solder, others cannot be satisfactorily made without the latter, so that for their construction some knowledge, at least, of two trades, the carpenter's and tinman's, is imperatively necessary. I cannot, therefore, draw a decided line between toys of wood and of metal, so, consequently, intend following a different plan, working from the simpler to the more complicated, and placing mechanical toys in a class by themselves. Practically, this will offer an advantage of another kind. The simpler toys will be within the powers of many of our younger readers, while the more complex will follow as the powers of these readers increase by practice, and will, in the meantime, afford recreation and interest to those who are already fairly versed in the arts of construction.

There is no difficulty in toy making, nor much in ordinary carpentering, to anyone who can fit a mortice and tenon joint well. But to do so entails first the accurate squaring up of the pieces to be framed together. This is the very first lesson to be learnt, and not an easy one. But it is no use to scamp work, whether small or great; and that dogged perseverance which will overcome most difficulties in this world is absolutely necessary to insure success in carpentering. It is for this reason I would urge toymaking on the notice of my younger readers as well as those of maturer years. It is not for the sake of the toys themselves, but to promote the practice of carpentry, that I determined to write this book. I want the manufacture of the toy to lead up to that of the real article, be it barrow, cart, roller, or the articles of furniture of a doll's house.

CHAPTER I.

ORDINARY TOOLS AND MATERIALS.

A LARGE number of the cheapest toys imported are made almost entirely of unplaned wood split up by the paring knife, such as is used by many turners in preparing wood for the lathe. This consists of a blade in the centre of a lever hinged at one end to the workbench, and with a handle at the other. The tool may be bought at the shops under the name of a paring knife, and although we may, perhaps, get along without it, it is well worth our attention, if not just at first, yet at no distant date, for by the time we approach the construction of better class toys, we shall find it of very great value. A simpler tool, however, for splitting up small pieces (an operation often required) is a shoemaker's or glazier's knife. The latter is made with leather sides, to form a handle, which saves the hand from the jar caused by the blow, and it is purposely made to withstand the blows of the hammer. It is called a hacking knife. The former is a useful tool, and is a good shaped knife for the work, having a handle of wood of sufficient size to afford a firm grip, while the blade is as long and broad as that of a short dinner knife, the handle of which is scarcely of sufficient substance for the purpose.

A small saw—a tenon or mitre saw—will certainly be needed for cutting across the grain, and a small plane to trim up the edges of the pieces. The little iron planes at one and two shillings each are very useful for this purpose, as well as for many others connected with household carpentry. A small gimlet or two (preferably twisted), two or three bradawls, a glue pot, hammer, and light mallet, with a couple of small chisels—one very narrow (¼in.), the other ½in.—will enable us to do a lot of simple work, our chief difficulty at the outset being the production of round pieces for wheels without a lathe to make them with; but, for early attempts, I will presently describe two fairly efficient substitutes. For nails we shall need small brads or sprigs, and these are, in some respects, preferable to the wire nails, of which, however, a small supply will be most advantageous. Gluepot and brush, with a half-pound or so of the best glue, must not be omitted. For the production of small round pieces of wood, the size of shillings and halfpence, for use as wheels, of which you are sure to need a good many, a gun punch, commonly used for cutting gun wads, and a centrebit, such as is used by carpenters, with the scooping part of it filed off, so as only to leave the centre point and plain cutter, will be required. You can make a punch of larger size if you can get hold of a bit of steel tube, but the gun punch is easily obtained, and you can get one of the largest. Probably you may meet with hollow punches, of still larger size employed by saddlers, plumbers, and others who work in leather.

There is, indeed, another tool used like a centrebit, the brace, by means of which leather, card, or thin wet wood may be cut out in circular pieces; but it is not generally procurable in country tool shops. It is a sort of expanding centre bit, ingeniously though simply made, and not expensive; but a small and cheap hand fret saw will do the work better, and serve for other purposes, which the article alluded to will not.

There is a simple little tool, called a bevel, which carpenters generally make for themselves of wood, but which may be made of wood and metal, or it can be purchased. This is almost necessary for the toy maker to set off such bevels as those to which I shall allude shortly. It is sketched in two forms in Fig. 1, A, B. It will be seen to be similar to a shut up pocket knife or razor. The best and simplest way to make it is to take the bit of wood to form the handle—mahogany, beech, ash, or some tolerably hard wood not likely to split—and after planing it true on all sides, to make a saw cut down the middle to within an inch of the lower end. This will at once form the handle. For the blade a bit of thin mahogany, hoop iron, old saw plate, or similar thin but stiff material may be used, a hole being drilled near the end for the rivet, and, to prevent splitting, a rivet and washers may also be passed through where the inch of solid wood was left at the other end of the handle. In the other, and more approved form, with long blade, the rivet is replaced by a screw and thumb nut, the former working through a slot in the blade. By this

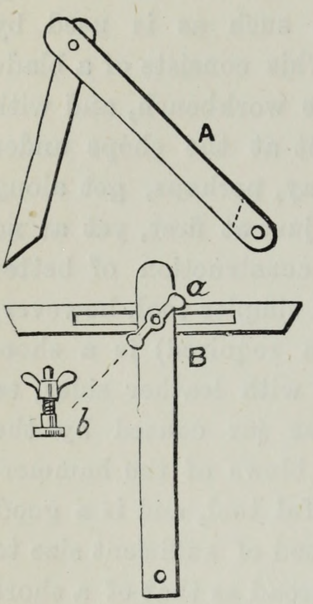


FIG. 1.—THE BEVEL.

means, when the blade is set to the required angle or bevel, it is readily secured and prevented from shifting by a turn of the thumb screw, *a b*. For permanent bevels, *i.e.*, where a large number of pieces are to be cut to the same slope, it is better at once to cut out a template or pattern from a bit of tin, zinc, or thin wood, and to work from this instead of using an adjustable bevel, with movable blade. The latter tool is first cousin to the square, and may be called a square with a shifting blade, which can, of course, be set at right angles to the handle, as well as to any other that may be needed.

Now and then our stock of tools will need additions, but this we shall allude to as the special necessity may arise. To recapitulate we shall start with the following :—

Small tenon or mitre saw.
Hack knife and shoemaker's ditto.
Two small bradawls.
Two small gimlets.
Glue-pot and brush.
Centrebit and brace.
Small hand fret saw.
Two chisels, ¼in. and ½in.
Hammer and light mallet.
Bevel.
Gun punch.

We shall hardly get on without a small hand saw as well, and I must pre-suppose a work-bench or strong table to be at hand.

Although we need wood such as willow or lime for purposes where a tendency to split would be a drawback, we need in very many other cases wood that will split with facility, foremost among such being clean yellow pine deal, free from knots and irregularities of grain. This last is generally more easy to obtain than the rest, as all carpenters use it, but I think all those named can be had, cut in neat thin boards, at such places as Samuel Smithers', and other advertisers of material for fretwork. Frequently, too, willow and lime may be had without much difficulty, but it should be cut into pieces of not more than ¼in. thick, and preferably ⅛in. The universal introduction of the fret saw has made such material far more common than before, as these woods are extensively used for fretwork and carving, and are kept sawn up ready for such work. For toys of a higher class we shall find oak, ash, beech, and mahogany serviceable ; but to use these we shall need a lathe of some sort which at the outset we should endeavour to do without.

Never buy inferior glue; it is cheap, but fit only to make size for painters and paper-hangers. Choose, instead of this thick tough abomination, the clearest, thinnest, and most brittle that you can get.

The preparation of glue is a most essential art, and very generally neglected. Young hands especially appear to think that the more thick glue they heap upon the work the stronger will be the join. The usual course is to put some pieces of glue in the inner vessel of the glue-pot, with some hot or cold water, half fill the outer vessel with water, and put on the glue-pot to boil as quickly as possible, give a stir, daub it on, put the pieces together, and imagine they must stick fast. This is totally wrong. Prepare the glue by putting it into cold water in the inner vessel some hours before it is wanted, and there let it soak. It will not dissolve, but swell considerably, and form a gelatinous mass. Put the pot on with plenty of cold water in the outer vessel and let it gradually boil. The glue will now quietly melt, and, if you have not put in too much in proportion to the water, it will not be stringy or thick, but will be about the consistency of cream, if not add a little more water and stir it. Never use it thicker than cream—it must run quite freely from the brush and not hang in clots upon the work. Perhaps treacle in summer, or clear run honey may be a better comparison to make, and I am particular in speaking about it, as glue is nearly always used too thick and in too great quantity, and thus keeps the parts separated instead of holding them in close contact. Hence a golden rule is to put on as little glue as possible, and also to let it be boiling hot, and the wood also well heated. Then if the parts are bound or clamped till dry the joint will be so good that the pieces will break at either side, and tear asunder the fibres of the wood rather than give way along the joint itself.

Another requisite for good work is a bowl of hot water and a bit of sponge, to be freely used at once to wipe off glue which has run out of the joint or dropped on to the work. For you must work quickly, not minding a chance splash of this kind, especially in glueing up a long joint. Any glued work must be clamped with strong screw clamps or otherwise till dry. If you have to join two edges—as, for instance, to unite two boards to increase the width—set one up on edge in a vice, or so that it will remain thus; brush glue along the edge, and also on that of the board to be united to it, for which purpose place the second by the side of the first, edge upwards, so that you can glue both at the same time; then laying the loose board in its place, move it a few times to and fro upon the other, and it will begin to stick; then quickly adjust it, and let it remain till dry. Long boards require two people to manage this one at each end, to keep the top one from slipping off as the work proceeds. Such joints, made by practised hands, are almost invisible. Of course the edges must be planed beautifully true, but we shall not have to deal with long joints in *our* work, and the glueing operations needed will be of the easiest.

In painting toys, which are vastly improved by bright and showy colours, it is a good plan to add copal varnish to the paint, as it gives it body and lustre, and saves you from having to varnish it afterwards. The so-called lacquers with which model engines and machines are coloured is made in this way. If it should become too thick to flow easily from the brush, it may be thinned with turpentine. Wash the brushes by rinsing in turpentine, finishing with soap and warm water. Varnish brushes, however, when intended for this purpose alone, may remain in the varnish, or, if strained and allowed to dry, a little hammering of the bristles will cause the varnish (which is then dry resin or gum) to crack and crumble to powder, which you can shake and dust out easily.

Paints can now be bought of all colours, ready mixed, in 1lb. and ½lb. tins; but the first coat should always be in lead, usually a grey or lead colour. Many colours have but little body by themselves, and sink into the wood, so that a great many coats are required to bring them to a good surface. Lead has great body and prevents this, and when dry other colours can be laid upon it to suit the taste. Any painter will mix you the colours required if you do not care to get the tins, but they are very handy. Nevertheless, I must confess that these tinned paints do not seem to me to dry very hard. The green I have known remain sticky for a long time, though sufficiently dry not to come off on the clothes. It is a question, however, of " driers,'' as it is called—a preparation of lead put into the oils to make the colours dry well and quickly—and which can be had separately at any painter's shop. If a coat of varnish is added after the paint is dry, it should be put on very thinly, and on no account is a second coat to be added till the first is quite dry and hard, or you will get a sticky surface and in every respect a bad appearance.

CHAPTER II.

EXPEDIENTS AND MAKESHIFTS.

UNDER this head are included various handy contrivances calculated to give assistance to the toymaker. Sometimes it may happen that he is unable to get a proper bench vice, and has to devise an efficient substitute to enable him to set upon edge, for planing, the small boards which he has occasion to use in his work. One of the simplest contrivances I have sketched in Fig. 2, giving a front and end view to render the arrangement clear. D, in the right hand figure, represents the front board of the work-bench, the shaded one being the top. To this front board is attached, by two screw bolts and nuts, a block (E), wedge shaped, as shown, and to this is held, by the same bolts, the stout front piece (A), also wedge shaped. In the righthand figure E is shaded as a section showing the bolt. C is the board to be planed, resting on the piece (E) and also against the face of the front board (D) of the bench. A wedge (B) is then driven in as shown, holding the work securely. Screw bolts are not always used for this apparatus, but not only do they hold it far more securely against the strain of the wedge, but when the nuts are taken off the whole comes

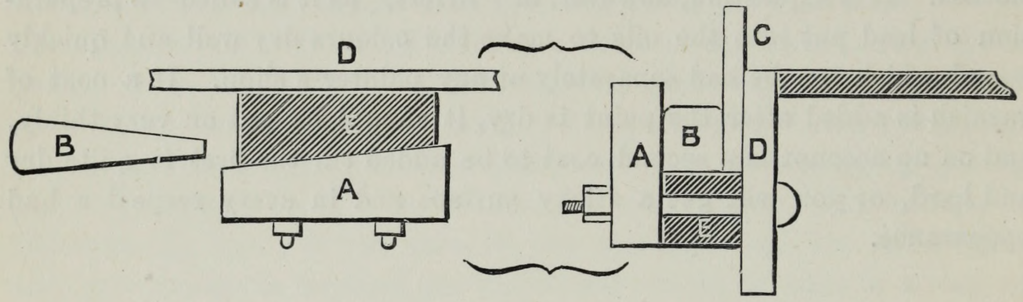


FIG. 2.—CONTRIVANCE FOR HOLDING BOARDS ON EDGE.

apart, and can be similarly fixed in any other place wherever an upright or horizontal board or squared post can be found as a fixture on which to fix the parts. It is only necessary to bore a couple of holes for the bolts, and the whole affair can be securely arranged in ten minutes. The wedge should be long in proportion to its thickness—a gradual slope—as it will take a better bearing and hold more securely; a slight tap will drive it tight enough to secure the work.

Another simple plan for holding a narrow bit of material on edge is that sketched in Fig. 3, where the shaded part is the top of the bench, with the usual planing stop (C). Instead of the end of the work resting directly against this stop, a piece of thick board, about 6in. long, intervenes, cut out in a large notch as shown. The thickness of this auxiliary piece depends on that of the work, of which the edge to be planed must, of course, stand a little above it, but the thicker it is the more support will it afford to each side of the bit of board. It is essential that the sides of the V shaped notch should be perpendicular, or the work will not stand upright; and, if preferred, the latter may be further supported by a wedge shaped piece on each side between it and the inside or walls of the notch, but this is not generally needed.

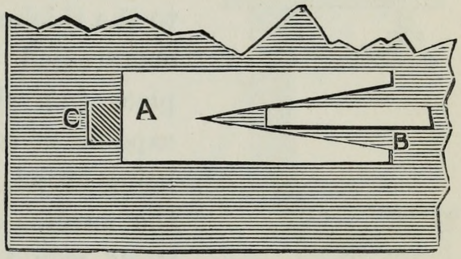


Fig. 3.—Wedge for Holding Boards.

A good plan is, however, to use the additional simple means shown in Fig. 4, especially if the strip is many inches in length. B is here in section the bench top, and A the strip set on edge to be planed. C is a bit of old saw plate, or steel plate of some sort, about 3in. long, sharp at the ends and lower edge, which is set up on edge against the end of the work and bench, and secured by a tap from the hammer upon its upper side. The angles thus penetrate the work and bench a little, driving the former firmly against the planing stop, and also holding it securely enough for planing. The backward motion of the plane does not draw back the work from the stop as it otherwise would. This contrivance is used by carpenters, with and without the notched auxiliary stop. I have spoken of it as a saw plate, but this is hardly so thick as it should be. There is no

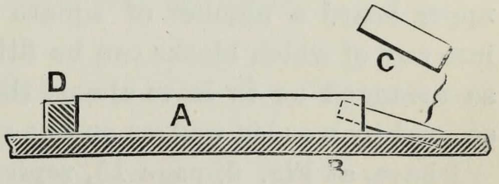


Fig. 4.—Planing Stop.

difficulty, however, in finding a bit of steel 3in. long, an inch or two wide, and saw plate will do, if it is part of a pit saw or tolerably thick hand saw. Where there are several pieces requiring to be thus planed on the edge they may, with advantage, be temporarily united, by being placed side by side and secured by a screw clamp at each end, or even by being tied with stout twine.

One of the best and neatest clamps for this purpose, as well as for many others, is an American one (Fig. 5). It is of cast iron, bronzed, about 4in. long. The sliding arm has in the mortice a spring which causes the mortice to catch in any one of the little notches cut in the back of the clamp. It is easily moved into position, according to the thickness of the work, which is then further compressed by a turn or two of the screw. The piece (A) which rests on one side of the work, is capable of turning upon the end of the screw, and, being broad, forms a better face, and does not injure the surface of the work, as the end of the screw itself would do. One great recommendation of the tool is its cheapness. It is to be had of Mr. Churchill, of Finsbury, who imports all sorts of American tools and "notions," all cheap and generally good. Two or three should be procured.

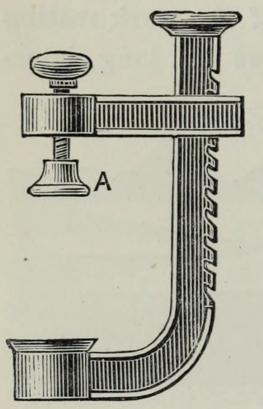


Fig. 5.—American Clamp.

The general practice of the trade seems to be to tack down on the bench a block or two of wood on each side of the strip to be planed, between which blocks it is held. When there are several pieces of the same thickness to be planed, this affords simple and efficient means for supporting them, and temporary expedients of the kind are very general in all workshops. A well-fitted bench, however, generally has in the upper board a number of square mortices at varying distances apart, into any of which blocks can be fitted to act as supports. If these are so arranged as to leave almost the requisite interval, the board can be secured by wooden wedges on one side.

I have, at Fig. 6, page 13, represented such a bench top and support showing the mortice holes so convenient for holding many kinds of blocks and supports. No one who has not practised carpentry can fully appreciate the great advantage of a good work-bench with a smoothly planed top of 2in. stuff, a good vice, and wood stops of various shapes. No one can face up a bit of wood accurately that shifts about under the action of the plane. It frequently happens, too, in toymaking that a bit of stuff has to be planed to an octagon shape, *i.e.*, after being squared up, the angles are each to be removed more or less. Here again we need blocks, but of a different form, like B, Fig. 6, which can be also made with a tenon to fit the mortice holes in the bench top. The ordinary planing stop will also be used, just as if these blocks were absent. They can be also cut out of 1in. boards, like C, and merely rest on the bench without a tenon, the piece to be planed being held between the planing stop and bit of steel or knife edge already explained. So held, it will have no tendency to upset these angular supports, upon which it rests. True, our present carpentry is in miniature, which only means that the apparatus must be proportionately small, and that the workmanship ought to be so much the neater, otherwise the operations are identical.

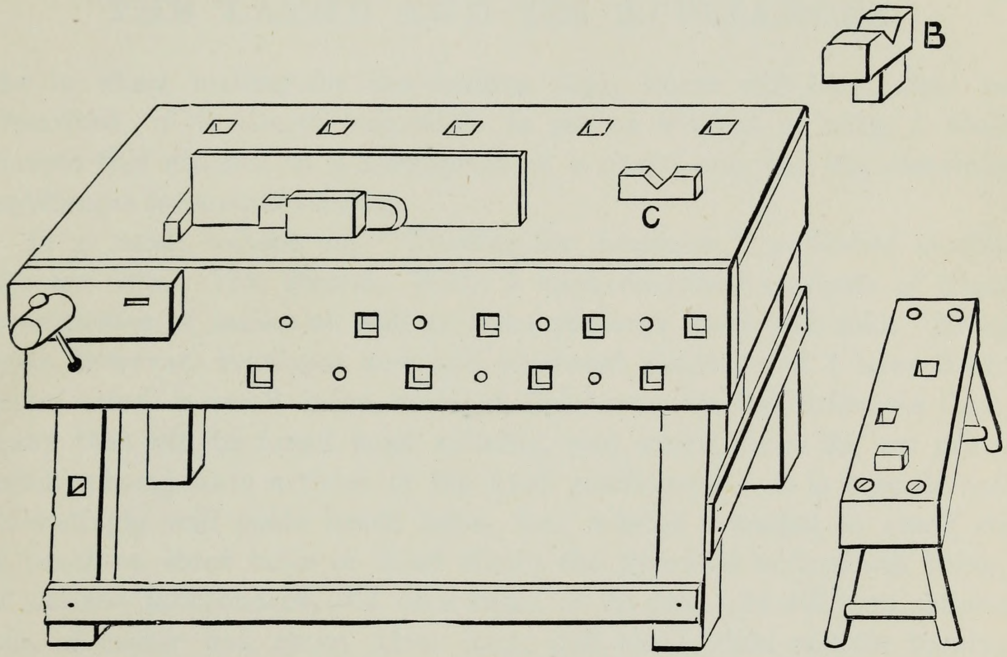


Fig. 6.—Bench and Stool with Mortice Holes.

In many cases, however, a plain table has to do duty for a work-bench, and will answer fairly well for much light work; but, in that case, if there is any mortising or much hammering to be done, a plank of 3in. stuff ought to be laid on the table to bear the concussion of the blows; and a common stool, like that shown also in Fig. 6, will be of great service, not only for placing stuff upon for sawing, but also when it has to be mortised or bored with the brace and bits, or trimmed with the hatchet. A small vice, which can be screwed to the table and removed at pleasure, will be necessary, but planing must be done upon the sawing stool, as a stop cannot be made to fit the table without damage ; a couple of nails driven almost home in the stool will answer the purpose should occasion arise. Other appliances will be described as we go on with actual work.

CHAPTER III.

THE LATHE AND ITS APPLIANCES.

As in wheel making for the various toys, which will hereinafter be described, it is almost impossible to get on without a lathe, I shall devote this chapter to a description of a useful one, and the necessary appliances for simple turning.

In a small volume on "Turning for Amateurs," published at *The Bazaar* Office, 170, Strand, W.C., I have described methods of home construction of lathes as well as some patterns made and sold. Every year, however, developes new and improved shapes, and I have lately come across a small lathe made at Colchester by the Britannia Company that will be found most suitable, and which, from its low price, renders home-made articles of the kind unadvisable. It is a small and exceedingly well made bench lathe, *i.e.*, a lathe intended to stand on a bench or stout table or fixed shelf; the fly-wheel underneath being, if desired, independent, and on a stand of its own. It will turn articles 5in. diameter and about 11in. long, and has a slide rest for turning metal, which can be omitted if desired. It is also fitted with two or three plain chucks. The price is £1 15s., and I am sure no home-made affair would prove so cheap, because all the parts are of good material well fitted together. On stand complete, with flywheel and treadle ready for use, the price is but £3 10s.; a rather larger one, to turn 6in. diameter, is £4 5s., complete. Small lathes of this kind will do all such work as is demanded in toy construction.

The lathe shown at Fig. 7 on the following page, is on a special table which is sold with it if desired, the under part being properly fitted to take the bearings of the flywheel and of the treadle. The side pieces, or legs, are called the standards, the cross pieces of ornamental shape are the braces, and these are very conducive to the stiffness of the frame, which is so important. The flywheel is mounted upon a fixed stud. A pin in one spoke forms the crank, and a connecting rod, called in America a pitman, descends to the treadle.

The bed is made with parallel cheeks or "gantrys," an ugly American term, and they are accurately faced on the top and edges. Between

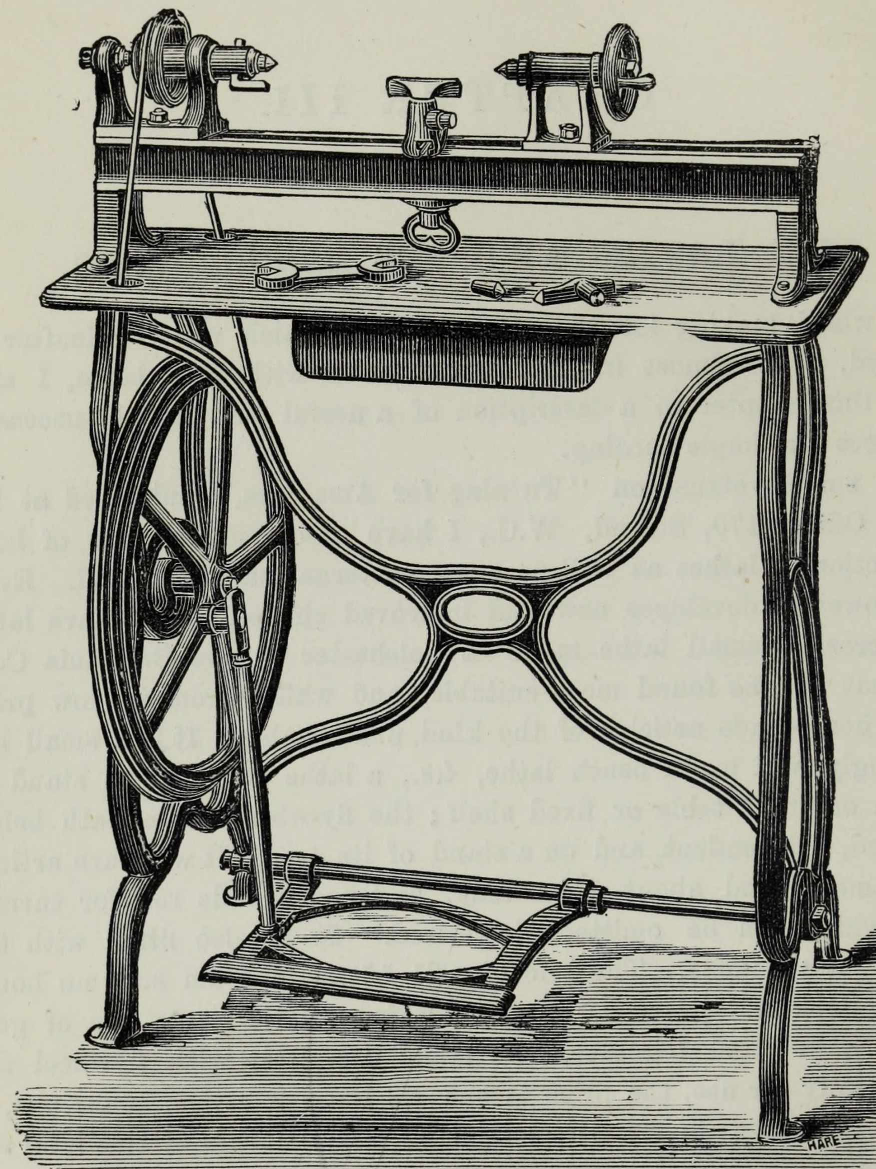


Fig. 7.—Lathe Suitable for Simple Turning.

them the poppit tenons fit accurately, but easily, and these poppits are secured by their respective bolts, fitted with nuts and washers, or holding-down bolts and plates, as they are also termed. The left-hand poppit is called the mandril head, and the two together are often termed a set of lathe heads, and can sometimes be purchased alone to fit up on wooden bed and standards. In the mandril head is fitted the mandril, which is the spindle which revolves and carries round the work to be turned. It generally runs in a collar at one end (the right), and against a pointed steel screw called the back centre or tail pin. The collar is usually of steel, very truly bored and hardened, but it is sometimes of brass or other metal, and is also not unfrequently omitted altogether, the mandril running in the cast iron bored to receive it. All the better lathes, however, have collars, and sometimes there are two instead of one.

The wheel on which the cord, gut, or strap is placed, and by which the mandril is driven from the flywheel, is called the pulley. It is here made of cast iron turned bright, but is often of brass, wood, or gunmetal. The mandril nose, or part which projects through the collar, is here fitted with a chuck—in this case a driver chuck. If this were removed, it would be seen that the mandril nose has a screw cut upon it, on to which the various chucks are fitted.

These queerly named articles—chucks—are intended to hold the wood or metal which is to be turned, and are therefore of various shapes. Some are for holding thin flat pieces of board, such as would be used for turning wheels, or platters, or stands of various kinds; others are for solid blocks, such as we should use in turning boxes; others for turning metal. The centre chuck, or driver chuck, on the mandril, is one of these. Then we have a hand rest, upon the T of which the tool is held; a rest consists of the sole which stands upon the bed, and is secured by a bolt and hand nut, the socket, or hollow pillar cast in one piece with the sole, and the T, or tee, which is made with a cylindrical stem to fit the socket, so that it can be raised or lowered and fixed at any height by the clamping screw at the side. The under side of the sole has a long undercut groove or channel, in which the head of the holding-down bolt fits, so that it can be drawn out or set in nearer to the bed according to the size of the work to be turned.

There are, in the case of larger lathes than the one illustrated, several such tees, some long, some short, and others, for metal turning, with flat tops, on which the heel of a metal-turning hand tool can rest and take a firm bearing. The other poppit is variously termed the sliding poppit, movable head, or back poppit, and its point, against which one end of the work rests when it is so long as to need such support, is called the back centre. It is generally removable, being screwed into the cylinder or fitting into it by means of a conical end. The lathe here illustrated would be said to have a cylinder poppit head and leading screw, because, by turning the hand wheel which is attached to a screw inside, the cylindrical piece of iron into which the centre is fitted is moved to and fro without itself turning round. This is now almost the invariable rule even with cheap lathes, but in old days the back poppit merely carried a pointed screw tapped into it. You may still find these—generally in wooden poppits in carpenters' and wood turners' workshops. They are, of course, far inferior to the other pattern, but where ordinary plain work is required, such as carpenters are called upon to do, these poppits serve well enough. The various parts of the lathe will, I think, be now understood by their technical names.

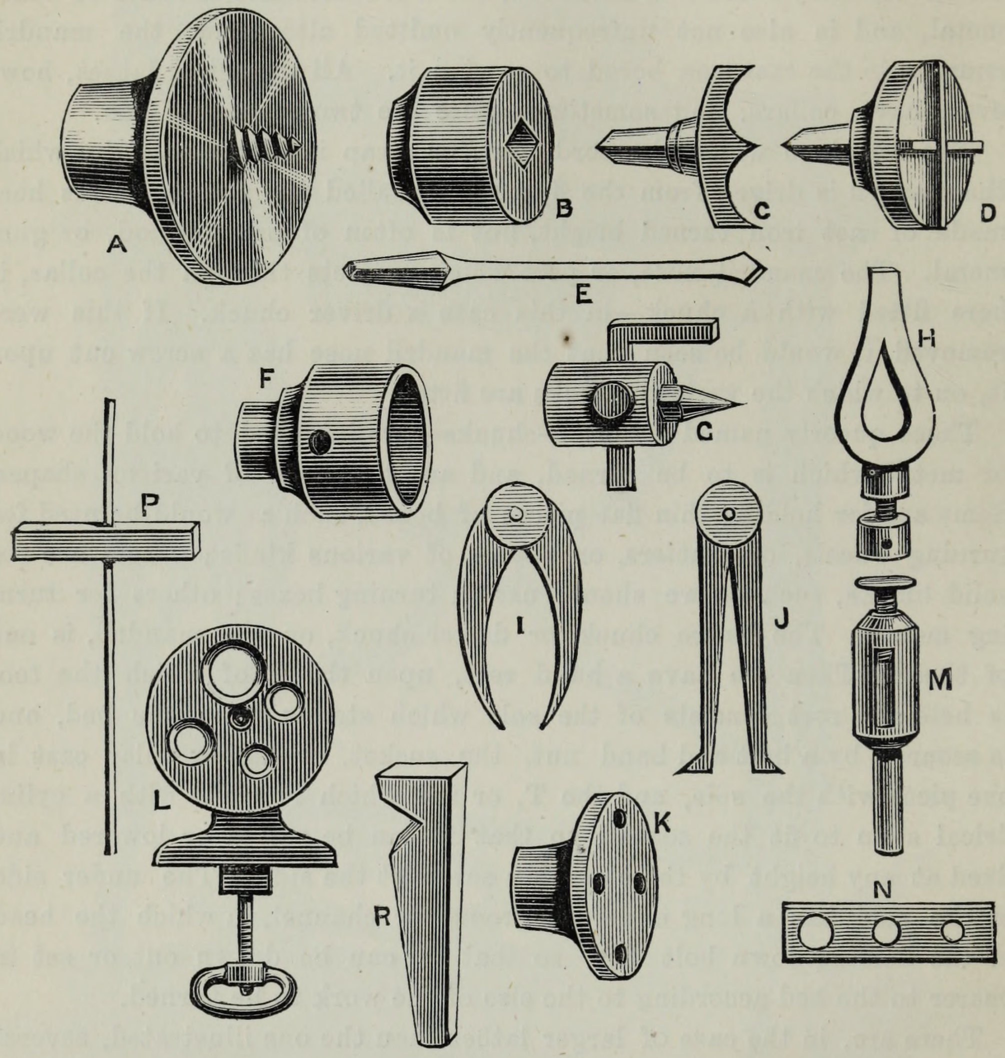


Fig. 8.—Chucks and Lathe Appliances.

At Fig. 8 I give a set of chucks and lathe appliances that are absolutely necessary even for such simple jobs as are required in the manufacture of toys. All the chucks screw on to the nose of the mandril. A (Fig. 8) is the taper screw chuck to hold short pieces of soft wood, which do not then need the support of the back centre. You may also use it to hold short pieces of box or hard wood, but must first bore a hole nearly the size of the large end of the taper screw with a drill or gimlet. All bits of board for wheels and such like can be held securely by this chuck. B is the square-hole chuck, and you can fit into it the fork, C; D, the cross fork; E, drills and boring bits with squared sockets, or small rods of metal or hard wood squared at one end to fit the hole, which is slightly taper. D, the cross fork, is for hard wood instead of C, which will not take a good hold. A couple of shallow saw cuts are made in the end of the piece to be turned, into which the projecting cross of steel falls. Of course, the saw cuts are made to cross each other at right angles, being, in fact, exactly like the face of this chuck piece. Wood is very firmly held thus, with the assistance of the back centre, and can be taken out and replaced to run truly, which is not easy with most chucks. Instead of the square hole chuck, however, a round hole is often used, tapering somewhat, and the forks and drills are more easily fitted thus to run truly. They are made with one side filed flat, and there is then a side screw to secure them. A square-hole chuck should, however, always be added, even if the round hole is used as well.

Next, at F, is represented a cup chuck. These are of wood or metal; generally there are a few of metal varying from 3in. or 4in. diameter down to 1in., and any others are made of boxwood, as they chance to be needed. Indeed, you will never get along without a lot of wooden chucks, which you will hollow out to the size you require; these are plugged and bored again and again till worn out. The metal cup chucks are handy, especially because you have not the trouble and difficulty of cutting the screw thread to fit the mandril, and, of course, if any one is too small or too big, and you have not the precise size needed, all you have to do is to drive in a plug of wood and bore it out to suit the work. But there is no occasion for a great many metal cup chucks, and it is better to make them of boxwood. I generally recommend from four to six as a sufficient stock of metal ones, and you can get on wholly with wooden ones if money is scarce.

G is the chuck that is ordinarily used for turning bars of iron or steel, and is seldom employed for any other purpose. The socket, G, screws to the mandril. It has a square hole through it sideways, to receive a cranked bar of iron or steel, which is secured by a side screw. A centre point is either made in one piece with it, or screwed in, which is the better plan. It is plain that if we make a central shallow hole with a punch or small drill at each end of the rod to be turned, it can be mounted between centres, as it is called, *i.e.*, held up by the back centre and that of the driver chuck; but if we set the lathe in motion, the bar will not turn with the mandril, as it only lies between the centres, and is not attached to either. Hence we need a carrier, H, of which various sizes are kept. This is slipped on the bar at the end next to the mandril, and is clamped to it by the screw. The tail of the carrier will now, therefore, as the mandril rotates, be caught and carried round by the pin of the driver, causing the bar to rotate also. When the furthest end of the work is turned to the required size, the carrier is removed to that end and the bar reversed, end for end, in the lathe. This is, in point of fact, an example of accurate work, supposing in the first place that the lathe centres are true to start with, and this method has one special advantage —that the work can at any time be replaced truly in the lathe if the drilled holes (called centres) are left in the ends of the bar, as they always ought to be. The form of carrier here given is that most commonly adopted, and from the pear shape of the opening it holds the work well, the screw driving the bar into the more angular part of the opening. There are, however, other forms, some specially made for holding square bars, others for screwed rods, but they need not be detailed here.

Another form of chuck, G, is sold—a flat face plate, with a projecting pin adjustable in a slot so that it can be put nearer to, or farther from, the centre point, which generally in such case fits in a hole bored in the end of the mandril itself. The pin catches the tail of the carrier, just as the bent bit of iron does in G. There is not much to choose between the two—on the whole, I like G the better; only one can sometimes use the other as a face plate, especially if it has two slots, as it ought to have. The pin fastens with a nut at the back of the plate.

I represents a pair of outside and J a pair of inside callipers for measuring the size of cylindrical work, solid and hollow. There are also made out-and-in callipers in one, but they are not much in use, as they seldom give accurate results. The intention of these is to provide means at once to measure hollow work with one end of the instrument, while the other gives the exact size of a cylinder that would fit it. K is a flange or disc chuck, used sometimes to hold bits of plank attached by short screws, inserted from behind, instead of using the taper screw chuck. Sometimes it is made only with little projecting points instead of screw holes, and the work is pressed against it by the point of the back poppit. It is, in fact, a small face plate, and is very useful for turning a disc of soft wood. This is made also of wood, but is better when of metal. L is a useful, if not indispensable, appliance, called a coneplate or boring collar, generally of metal. The lower part is a low poppit, the circular part a disc of iron ½in. thick, which turns on a central bolt, by which it can be securely fixed when required, so as not to turn round or shift its position. Holes of graduated size are made in it as shown, each being conical and turned smooth, the largest part of the holes facing the mandril when in use. Its object is to enable a turner to get at the end of a long piece of wood or metal in order to bore it, which, of course, he could not accomplish while it was supported on the back centre. He therefore removes this, and, selecting one of the holes of the cone plate that will admit the end of the piece, but will not let it pass entirely through, he places this hole upwards, turning the plate round until he sees the work run evenly and truly. Then he fixes the poppit by its holding-down bolt and clamps the round plate by its centre screw and nut, taking the back poppit away altogether. The rod cannot escape or get loose, although the turner is able to get at its end with a drill or boring tool.

Another way of making this appliance is to have a bit of iron or hard wood like M, the tail of which fits into a hand-rest socket and in the slit of the upper part of which a straight slide, N, fits nicely. This slide has a set of conical holes like those of the circular plate, and can be adjusted to the required position, and clamped by the screw on the top of the part M. Even if M is of iron the slide is very generally made of wood. P is called a turner's square, or depthing gauge. You can make one so easily that it need hardly be bought. Take a bit of hard wood, and plane it up to the form of a strip about 2in. or 3in. long, ½in. wide, and about ¼in. thick. Drill a hole through it exactly at right angles to its length, and large enough to allow a steel rod—a knitting needle of medium size—to pass rather stiffly through it, and it is done. You use it to gauge depth by putting the needle inside the hollow and sliding down the bit of wood till it rests on the edge of the work across the mouth of the hole. By keeping the needle against the wood inside the hole you also find out if the work is square. If bored truly and not conically, the wood slide will rest evenly across the mouth of the hole. These instruments can be bought, beautifully made in gunmetal, with either a flat or round steel slide; but for toy-making and other woodwork it is just as well to have it home made—only the hole in the wood must be correctly bored. To do so, mark all round with the square, and with a gauge (like that described already) make a line across it on both (opposite) sides, and bore where the lines cross each other, half from one side and half from the other. This should be done with a drill slightly smaller than the needle or steel rod, and must be followed by another, very little larger, run quite through at once to finish and smooth the hole. In this way you can always bore a hole accurately in any direction, because you mark the point of its entrance and exit first, and insure its going truly from one to the other.

There is very little lathe work that cannot be managed with the chucks and fittings I have here described and illustrated, and few regular wood turners have more. The only addition, perhaps, is a backstay, a very simple affair as ordinarily made by workmen. It is a wedge-shaped bit of ash, or elm, or beech board, about ¾in. thick, with a notch sawn in it, as shown at R. The smaller end is placed between the cheeks of the lathe bed, and the rod which is being turned rests in the notch—this prevents the rod bending under the action of the tool, which is the only object of a backstay. A wooden wedge is driven in behind this stay to keep it steady and in light contact with the work, but it must not press against it so as in the least to spring or bend it. There are much more elaborate affairs sold for the same purpose, but, except for rods of metal, none is much more effective in use than the simple one here illustrated, which is commonly used when broom handles, curtain rods, and similar plain articles are turned, which are too long and slender to withstand unaided the application of the turning tool. It is always better to turn without it, notwithstanding, when possible.

The many turning tools used by those who work in wood and metal, and especially those who practise ornamental turning, are not required for toy-making. A couple of gouges and chisels will do most of the wood work, and for metal, a graver for iron and steel, and a round and flat tool for brass, will enable a great deal to be done. But when I come to speak at length of toys made of metal I may have to call attention to one or two more.

CHAPTER IV.

SIMPLE TURNING.

I WILL now describe the actual use of the lathe and appliances detailed in the last chapter. First as to simple discs of wood to be used for wheels. For these you need only a parting tool, which is very like an exceedingly narrow mortising chisel, but it is ground away on each side of the edge so that it may not jamb in the cut as it proceeds. If you have no such tool, a small mortice chisel will answer, and, indeed, I have frequently used it.

You must first plane the bit of thin board $\frac{1}{4}$in. or $\frac{3}{8}$in. thick on both sides, and then cut off a square piece large enough to contain a circle representing the wheel or disc required. Draw lines from opposite corners, cutting each other in the middle, and where they cross bore with a gimlet a hole nearly the size of the bottom of the taper screw of the chuck A, this being the one to use. Screw on the piece till it rests quite flat against the face of the chuck, which should be first screwed on to the mandril nose. The work is now securely mounted. Loosen the holding down bolt of the rest and also the screw which secures the T, bring the rest up to the work, turn the T so that it lies flat against and almost touching the work, and adjust the heighth of it, which should be a little below the line of centres; this will bring the edge of the tool upon that line, or nearly so. In this case it is not important to place it exactly at that heighth, but it is as well to have it thereabout.

Now set the lathe in motion, give it a fairly quick speed, and bring the tool gently up to it. When you set a square piece into rapid rotation it looks circular, so you are to take special care to place the edge of the tool fairly within the square, or else the angles will catch the tool, and the result will be, in all probability, the speedy detachment of the wood from its chuck, while it will be split in half, and have to be replaced by a new piece. Proceed carefully, therefore, in this respect, and advance the tool gently, especially when nearly through, which it will be in a few seconds, and presently the outer part will drop off upon the tool, leaving the disc or wheel upon the chuck.

Of course, we can hardly call the operation here described turning; it is merely holding a tool almost still against the face of a bit of board, which board was previously made smooth by the plane. At the same time you may do it well or badly. The wheel may be true on the edge and square to the face, or it may be conical, and in any case it may not be smooth. If needful, it may now be trimmed to greater accuracy with a chisel or a gouge. The chisel is the right tool, but must not be held on the rest as now placed, but the tee must be turned round to lie parallel to the lathe bed, and may also be raised much higher, even almost as high as the top of the wheel. Then the chisel can be held almost horizontally, but so as to cut off a very thin shaving, else it will hitch in and split off a bit of the wheel and spoil it. If it is of deal, which splits very easily, there will be still greater danger of this mishap. What you have to attend to is to make the chisel cut and not scrape. If you turn the T of the rest round, keeping it level with the centres, and lay the chisel flat upon it with its edge in contact with the work, it will scrape and not cut smooth; if you hold it at an angle, sloping the handle downwards a good deal, it will cut, but to slope it sufficiently you will have to hold it so low that it will be awkward to use; but if you raise the rest nearly to the top of the work as it revolves, the chisel will be at the necessary angle without having to be held thus awkwardly, and you can make it cut the wood nicely and detach a very thin shaving, which is just what you require.

An easier tool to use is the gouge, but it is a little awkward in this particular case if the wheel or disc of wood is of less size than the chuck, because the tool then touches the face of the chuck; if it is larger and the gouge is held even at a much greater angle to the work—*i.e.*, not nearly so slantingly—it will cut the wood smooth, and the tool will not catch in. It is not so very important that the edge of a toy wheel should be smooth, but as it affords a lesson in the use of the turning tool, it will certainly be advantageous to finish it in this way. I think that it is quite as well not to allow a novice to use a chisel at all for some time—not, in fact, until practice has enabled him to keep up the treadle action without swaying the upper part of his body and so causing the hands and the tool to partake of the motion of the legs. After a while the turner will find that the lathe wheel almost runs of itself, so unconscious does he become of leg work while concentrating his attention on the tool, and he will find no difficulty in standing as steadily on one leg as any goose. At first, however, he will find the treadle work not only laborious, but a source of trouble, owing to the unsteadiness it causes to the arms and hands and, consequently, to the tool. I do not mean, by the by, that leg work at the lathe with a bit of stuff some 6in. in diameter is not sufficiently laborious to be felt—far from it, but that when the knack is acquired of driving the lathe in this way the attention is no longer given to it, but concentrated on the work in hand, while the leg moves, as it were, automatically, especially with a light running flywheel.

To avoid a hitch in, which is the evil common to beginners, attention must be given to the form of tool in use. The gouge may be used with far greater freedom in this respect than the chisel, as learners speedily discover. But why? Simply because there are no points terminating the edge, the curved form of which lifts the extremities of the cutting edge clear of the work. But you may nevertheless so use a gouge as to make it catch in.

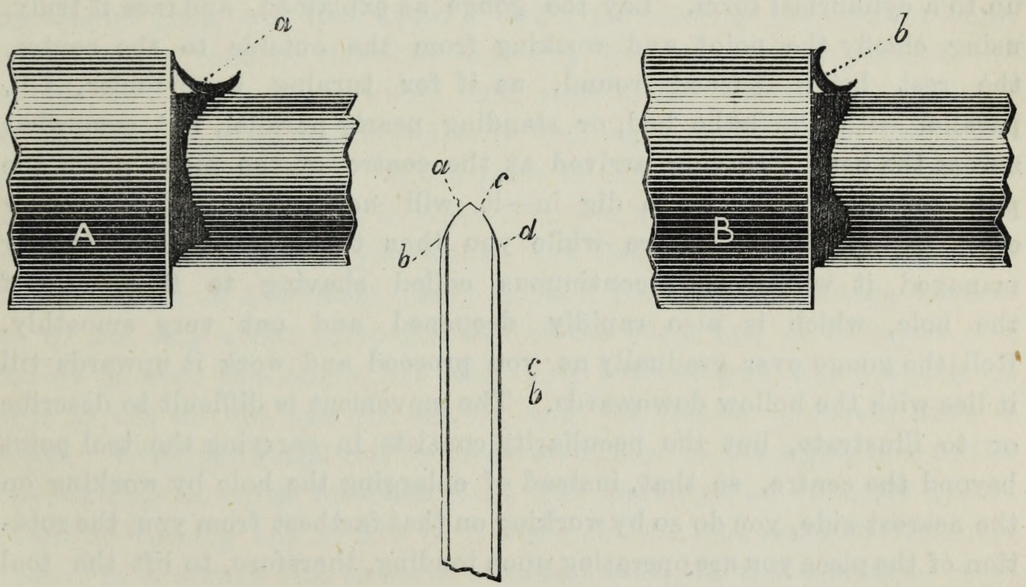


Fig. 9.—Wood Turned with a Shoulder.

In Fig. 9 A is represented a bit of wood turned with a shoulder, *i.e.*, a part of it is higher than the rest. Place a gouge at *a* in the position shown, and the left side of its curved edge is sure to get caught. Hence you must so place it as entirely to free this edge, *i.e.*, place it like *b* of B, in which position you can face up also the shoulder itself, but when you get down to the corner you must take care that the opposite edge is not now caught by the smaller cylindrical part of the work. The end of a gouge is like *c*, *i.e.*, it is of an elliptic or somewhat pointed form, so that with a little management you can get into tolerably small corners, but in turning cylindrical pieces after they have been roughed down it is usual to lay the tool on the rest, so as to bring into action the sides of the edge, *c* to *d*, or *a* to *b*, instead of the point, thus making a near approach to the chisel. With this you can level a cylinder very fairly. As a rule, use as large a gouge and chisel as the work will allow, a broad chisel being more easy to manage safely than a small one, because its corners are more easily kept clear of the work.

From what I have just said it will be clear that to face up a shoulder or to smooth the end of a cylinder with a gouge, the bevel of the tool (the part where it has been ground) is to be laid nearly flat against the wood, the hollow part of the tool being, therefore, outwards. Thus held, it can be used with safety, and will make good work. From this we shall get at the method of hollowing out a bit of wood with the same tool, which is a peculiar way of using it, but a very effectual one. We will suppose a bit of wood driven into a cup chuck and already turned up to a cylindrical form. Lay the gouge as explained, and face it truly, using chiefly the point and working from the outside to the centre, the rest being turned round, as if for turning a cylinder, *i.e.*, parallel with the lathe bed, or standing nearly parallel, but somewhat across the bed. Having arrived at the centre of the piece move the point of the tool so as to dig in—it will not catch—and gradually carry it beyond the centre while you thus turn it inwards. Rightly managed it will cause a continuous coiled shaving to flow out of the hole, which is also rapidly deepened and cut very smoothly. Roll the gouge over gradually as you proceed and work it upwards till it lies with the hollow downwards. The movement is difficult to describe or to illustrate, but the peculiarity consists in carrying the tool point beyond the centre, so that, instead of enlarging the hole by working on the nearest side, you do so by working on that farthest from you, the rotation of the piece you are operating upon tending, therefore, to lift the tool off the rest. The rapidity, however, with which soft wood can be thus hollowed out is very remarkable, and it is altogether well worth the pains necessary to acquire the knack of using a gouge in this way.

The only part you cannot get at is the angle inside a deep hole, such as the inside of a match box. For this in soft wood there is a special tool, but it is so seldom found in an ordinary turner's shop that I do not recommend it. It is very difficult to use, and a chisel may be substituted for it just to clean out a corner, or an inside tool, such as is always used for hard wood. A regular turner does nearly everything with his gouge and chisel, and the array of tools which are seen in an amateur's tool rack are seldom found elsewhere. The more the learner practises with these two simple tools alone the more speedily will he become a good practical turner.

I have already stated that the gouge is a much easier tool to use than a chisel. The latter, as used by turners, is ground slantingly at the end, so as to make one point much more acute than the other. It is also ground or bevelled on both sides alike, so that it can be turned over and used in either direction. The difficulty in using it is to keep both the angles clear of the work; if either catches it immediately digs in and tears the surface. As the chisel has a slanting edge, it is easy so to place it on the work as to keep the sharpest angle clear, *i.e.*, above it; and if you keep this upper one free, the other will not catch in.

Some use the keenest angle as the lower one, in which case keep the blunter angle clear; but the more usual and orthodox plan is to keep the sharper angle upwards, and always to work downhill, with the blunt angle leading, *i.e.*, if you are turning a cone or a tool handle with a hollow or smaller part, and then again a larger part just by the ferrule, begin at the larger, and go downhill *each way* to the smallest part of the handle, so that the two downhill cuts meet at the bottom of the hollow. If you try to work uphill you only work against the grain, and good smooth work is hopeless. If the piece is to be made level, and has no enlarged or hollow part, it is plain that you may lay the chisel flat, and work in either direction you please, but then again you must keep the highest angle of the chisel clear; in fact, you must so manage matters as to use only about three-quarters of the edge, and at first you will hardly do even this safely, but after long practice you will probably be able to use all but just the angles, and yet seldom or never have a hitch. When the chisel can be freely used, now to the right, now to the left, cutting in either direction clean thin shavings, no difficulty will be found in turning any article in a workmanlike and masterly manner. Hence it is always best to begin with soft wood, as the substance most difficult to work, hard wood requiring different tools and a different method, far easier to learn.

If you can get half an hour in a turner's shop and make use of your eyes, you will learn a deal more than a book can teach, and if the turner be a good-natured fellow he will perhaps be amenable to the gentle influence of a half-crown and teach you a little practically, though, I confess, I have not found this always easy. In London, however, there are now professionals who make it a part of their business to give instruction to amateurs at a stated price, and beyond all doubt this is by far the best way for the latter to learn the art.

The hard wood tools include the gouge and a flat tool or blunter kind of chisel ; but these are supplemented by many others—inside tools, right and left side tools, round and point tools, parting tools, beading, and some others used for special work—to say nothing of sets of hand chasing tools for cutting screws. The best way for a novice is to go to a tool shop and get about a dozen, the price averaging 8d. each, handles 1d. or 2d. extra, if of beech or hard wood with good ferrules. Take beech by preference, unless you wish your temper tried by the tools when in use dropping out of their handles. But I will give you a wrinkle : mix and melt together some resin and brickdust, warm the tang of the tool till it arrives at about boiling water heat, dip it in the mixture, and drive it gently home in the handle. The tool will then hold well. But first observe that people are apt to expect a square tang to fit a round hole. The latter is always drilled, and it is a good plan to keep a bit of steel the shape of a tool tang, which can be heated red hot to burn out the hole a little way. It needs a mere touch, and then the charcoal formed by the operation should be just cleaned out by means of a small file, and the tool carefully fixed as directed. A little extra trouble is well bestowed, and will save future annoyance. I have myself had tools drop from their handles by the mere act of putting them up in the tool rack, especially when the handles have been made of ebony or other hard wood. For metal turning tools ash or beech is far preferable, and so it is for those intended for other work.

The hard wood tools are all bevelled on one side only, and are not strictly cutting tools, as their action is more of a scrape ; still, when in good order they detach shavings and leave a good surface. Most of these tools are held horizontally on the rest, so as to bring their edges (bevel below) on the line of centres. The gouge is first used to rough down the stuff, unless it is very hard, in which case it is sometimes roughed down by a point tool or a small round end tool. The hard wood gouge is ground to a shorter bevel, so as to form a more obtuse edge than that needed for soft wood, which latter cannot be too keen. To avoid digging a channel in the face of the stone, lay gouges across it while grinding them, and roll them over to and fro upon their bevel. They are finished on slips of oilstone rounded at their edges, and called gouge slips. You can get them of all sizes to suit the sizes of the gouges, some of which are more than an inch wide, while others run as small as ¼in. or even less. Two at least should be had, ½in. or ¾in. and ¼in.

To hollow out a bit of hard wood begin with a drill or a small round end tool. There are drills made for this work which fit in wood handles like other hand tools, but a twist drill fitted thus is best. Then enlarge the hole with a right side or inside tool, and extend it to the required size, finishing the bottom (if a box or similar article) with the end of a flat tool, or with a carpenter's common chisel. If the inside is to be bellied out like a child's top there are inside tools on purpose. They are, in fact, of all possible shapes. Do not get any moulding tools, however, nor any that you can do without. Perhaps the following list may be of service in the purchase of them: two gouges, ¾in. and ¼in.; two chisels, 1in. and ½in.; two parting tools, one for soft wood and one for hard; one point tool; two round (one very narrow, cutting at point and edges); one flat; one right hand, or inside tool; one left ditto. These will do a lot of work if used skilfully, and can be added to as required.

Hand tools will suffice, I think, for all toy work, even inclusive of small engines, and everything that can be so done should be, in order to acquire skill in the use of hand tools before proceeding with those ordinarily used in the slide rest.

For metal turning the list of necessary tools will be found to be very simple, a couple of gravers, a triangular tool, a round end, a point tool, and a flat tool, with one or two inside tools for brass, and, of course, a few drills being all that is required. The triangular tool may be made of a three square saw file with the teeth ground off on each face and the point ground off at a small angle so as to produce a little triangular facet. The graver may also be made of a square file with its teeth similarly removed and the end ground off cornerwise at an angle of 45deg. (a mitre), so as to give a lozenge shaped face. Whether economy, however, is a great object in the case of tools which may be bought for 4d. or 6d., and of which two at most are needed, is a question for the toy maker, but saw files may be had for nothing, or at most for a penny, and it is an easy matter to convert such into tools. Files are very hard and brittle, but the temper may be slightly reduced by laying them on a plate of red hot iron and watching till the colour is a deep yellow and begins to turn to a purple, and then dropping it into a pail of water. Thus tempered, the point will be less liable to break, but for my own part I generally leave them quite hard. In a similar way you may make excellent flat tools for brass out of a flat parallel file which must be ground off quite square at the end and sides; and a square taper file, broken off to a length of four inches, and ground flat on each face and on the end, but tapering somewhat, will be found most useful for turning brass. It will do inside or outside work, using either of the angles as the edge, and the square end will also come in for many an odd job. Tools for brass work must never have sharp edges; they are ground off quite square or to a very obtuse angle; but iron and steel work need acute edges.

To use the graver, which will always give excellent results when once the way to use it has been apprehended thoroughly, I might almost repeat the directions I gave about the turning chisel, viz., lay the bevel or face almost flat against the face to be attacked. This face will be the right hand end of a bar or cylinder that is to be made true; and, thus laid, but with scarcely more than the point of the tool in action, it will immediately begin to cut a small neat shaving, the upper edge of the lozenge-shaped face being the cutting edge. Thus it is evident that the graver is held with one of its angles upon the rest, which angle will take a hold and prevent the tool slipping away from its work. The graver is not to slide along the rest like a gouge or chisel, but held in one spot, and turned upon it as upon a fulcrum, and the point of the tool as it advances will describe a short curve, and presently get out of cut. As soon as it has done so the tool is shifted forward to a fresh position. The work is thus done by a series of cuts, each extending perhaps ¼in., and ultimately the bar is made true by the application of the same tool, so used as to bring one of its edges parallel to the work, or by a flat tool, and it is generally finished with a file while still revolving in the lathe. The natural result of using a graver in this way is to form a series of hollows which are thrown into one by the flat tool, but the graver works splendidly in skilful hands, detaching shavings of good size, and being under easy control even by one hand alone. The leverage is wholly in favour of the turner, so that little force is needed to keep the tool cutting.

Another very useful tool which has been spoken of is the triangular tool. The angles of all equilateral triangles are of 60deg., so that if such a bar as a three-square file is made into a triangular tool as suggested, each of its angles will be of that size which is the same as the edges of a graver, and specially suited to turning wrought iron or steel. If you buy a triangular tool at the shops you will get one like a triangular file with its point ground off, and the sharp angles hammered down all along the shank to the tang, except for an inch or so at the end, which is the cutting part. You can grind off the angles of the file, but it is not worth while, though only an inch next the point may come into actual use. A little of the point may be taken off, but not much, as it enables you to get into awkward corners. A file thus ground is also used as a scraper to finish flat plates to a perfectly level surface; but this the toy maker need not trouble about. The chief use of a triangular tool is to face up the end of a bar, and to turn the inside of hollow work. It cuts keenly, and either edge can be used at pleasure. The same rule, for its position, is to be observed as that laid down for the graver, viz., to lay one face nearly flat against the surface it is to cut, merely tilting it just enough to make the edge bite. You will soon see what a powerful tool it is, and what delicate or deep cuts can at pleasure be made with it. Like the graver, too, one angle is laid on the rest, on which it gets a firm hold, and on this angle it is rolled over slightly this way or that to make it penetrate deeply or the contrary. In metal turning the rest is always put very close to the work to assist in steadying the tool. In using this tool for inside work one angle is so placed as to cut it a *little* above the centre line—a very little is taken at a time, say one-eighth to one-quarter of an inch—and then a little more, so as gradually to work inwards, clearing out a succession of narrow rings, which are afterwards thrown into one by using the whole length of the tool. Not, however, all at once, but making good use of its curved form, for the several edges are curved in outline, so that you cannot bring a great length into cut at once, but can begin at the point or the heel, and, by a slight movement of the handle, make each part of the edge cut successively. This, again, is difficult to describe, but, taking the tool in hand and using it as stated, my meaning will at once become clear.

Hollowing out is by no means such easy or light work as turning the outside of a bar, and is, of course, more fit for slide-rest tools; but I wish the reader to know that these are not by any means absolutely necessary.

If an attempt is made to turn brass with a graver or triangular tool, as I saw recommended in a book on model engine making (which also gave instructions for soldering with a redhot iron, and for grinding valve faces on the surface plate!), it will be found to catch in and take a huge bite. This metal needs tools with comparatively blunt edges—80deg. or 90deg. angles instead of 60deg.—a flat file, for instance, ground off quite square on the end, or a square section file similarly treated, and, of course, with the teeth ground entirely away, will make a good tool. The set consists of round end tools or routers for roughing down work, point tools for turning angular grooves, flat tools for facing and finishing. Although the angle of edge necessary is a large one—80deg. or 90deg.—yet this must be sharply ground, and the extreme edge not rounded off by careless grinding. Such a tool held tilted on the rest on its opposite angle will cut very nicely, and take off sufficiently large shavings if desired, but it is better to take several light cuts if time is no great object. Inside work is done as it is with iron, only the square tool is used instead of a triangular one, or an inside tool similar to that used for hard wood, with a single bevel underneath, the edge being ground to an angle of 75deg. or 80deg. This tool is held quite flat upon the rest, so that its cutting edge lies just above the height of centres. In all outside work on metal keep the edge exactly on the level of the line of centres, though this is of somewhat less importance with hand tools.

The T of the rest for metal turning is often required to be flat on the top, and quite broad, so as to allow the heel of the tool to get a firm bearing upon it. This saves also the ordinary T from becoming damaged on the edge by indentations, which prevents a tool used for wood or the screw chasers from sliding evenly along its surface. If such an indented rest were used in chasing screws, the process would be sure to fail; hence a T should be kept for metal, and that used for wood ought to be retained for that purpose only. If, however, at any time you are obliged to use an indented one, take a file and level its edge neatly, erasing all the indentations and notches. Finish by *drawfiling* it, *i.e.*, take the file by both its ends and draw it a few times up and down, holding it across the rest just as you would hold a double-handled shave or draw knife in levelling a piece of wood. In screw-chasing especially a perfectly level rest is essential, as the slightest check to the traverse of the tool will produce a waved or "drunken" thread, or entirely spoil it by running one thread into another.

The operation of drilling in the lathe is very often necessary. Sometimes the drill is made to revolve, and at other times the work. In either case strike a centre punch into the piece at the place where the drill is to enter, or mark it otherwise by an indent sufficiently deep to insure the exact position of the drill at starting. If the work is running in the lathe—held in a chuck—bring up a point tool, or the sharp angle of a graver, and turn a central hole to guide the drill; then bring the back centre up against the other end of the drill, and, holding it by a vice or clip, so as not to let it revolve, gently advancing the point of the back centre, you will drill as true as a hair. But if you begin badly, which generally results from not being careful enough in making the indent or hollow centre, the drill will wobble more and more as it proceeds, and the hole will not be true. Probably the drill will be broken, if a small one.

If the drill is running in the lathe, you have to work differently. In some cases, as in drilling a hole through a capstan headed screw for the lever, you have to mark it on both sides with an indent, one for the drill point, the other for the back centre point; you then drill a little way on one side of the head, and then reverse it and start on the opposite indent, thus you get the exact line set out that the drill is required to take, and by drilling partly from one side and partly from the other you make sure that the screw head shall be drilled straight through as it ought to be in the plane of its axis. When the holes nearly meet you have to be careful to advance the poppit cylinder very slowly, else it may happen that the drill suddenly twists through and jambs, breaking short off, or becoming, at all events, damaged; be careful also at this crisis to hold the work securely, or it will slip from the fingers. Of course you ought to use twist or fluted drills now that they are so easy to obtain and so well made, at least the smaller sizes; large ones are expensive.

A drill $\frac{1}{16}$in. or $\frac{1}{8}$in. diameter, for example, will cost about 4d., but a $\frac{3}{4}$in. may run as high as 6s. They are well worth the money, if much metal work is to be done, but a self centreing chuck must be procured to hold them. For toymaking, including small engines and mechanical toys, half-a-dozen small sized ones will suffice at about 3s. or 5s. the set. I have introduced drilling here because it is now almost a detail of lathe work, special drilling apparatus apart from the lathe being seldom required, and when it is, a small Archimedean drill stock will answer for most light work, but get a good one of steel with good drills, and not the rubbish at 6d. or 8d. sold in the streets. These are made of iron, and so are the drills, or if of steel, of the worst quality, and the drills will not fit the stock. I have tried them and speak from experience. Moreover, cheap Archimedean stocks are never fitted nicely at the head, which, after a very little use, will wear slack and wobble about anyhow or nohow, and your money will prove to have been wasted. A plain old fashioned bow drill is far better than these cheap tools, and you can make it yourself.

I may mention, by the bye, a very nice useful drilling apparatus at 1s. 6d. or 2s., by Cohen, of Kirkgate, Leeds, who sells all sorts of watch and clock tools, small files and wheels and screws, &c., that are often not easy to procure in country places, and a small parcel by rail would cost but 4d. or 6d.; you can also get at this place another very useful tool, viz., a small tap set in a handle, to tap the holes for small screws, such as can now be had by the dozen. All you have to do when ordering screws of this kind for small engines and models is to order the tap to match them. Only two or three sizes are likely to be required, but you may need several of each, and can buy far cheaper than you can make them. Then again, you will learn the value of standard sizes, and will keep drills just suited to drill the holes the right size for tapping.

All work now-a-days is being made thus when required in quantity, so that the various machines may have their several parts interchangeable, and any part lost or broken can be renewed from the manufactory, with a certainty of fitting, and without the necessity for sending the machine itself to the maker. In model making, for example, one engine is not made complete before another is begun, but a dozen or more cylinders are bored, and the ends faced to one exact size, then perhaps a dozen or so of cylinder covers are turned, any one of which will fit any other, and while the turner is doing this, another workman has been getting up a lot of bed plates or guides, while a third has been at work upon some one part of the boiler, making several pieces one after the other up to a certain point, but finishing none. An amateur will, of course, proceed differently, but he should learn to work to a given scale, and not drill all sizes of holes, and then have to fit special screws to them because they are not made of the accepted standards recognized by the trade. This, indeed, is not exactly a lesson in lathe work, but it is so just in this particular, that all turned work should be brought as far as possible under the law of standard sizes, or much extra trouble and difficulty will be met with. Twist drills, for instance, are made to gauge, rising by eighths, or sixteenths, or thirty-secondths, and thus they are arranged, in a great measure, to suit standard sizes of bolts or screw taps. If you want to make a $\frac{1}{2}$in. screw, you must select a drill to bore the nut or hole it is to fit one size smaller—say a drill $\frac{15}{32}$ or $\frac{1}{32}$ less in diameter than the tap, or $\frac{1}{16}$ less if for a larger screw, or $\frac{1}{8}$ for a still larger, according to the depth of its thread. All this is provided for in the sets of drills, the smallest rising by sixty-fourths, because the threads of small screws are so fine that thirty-secondths would be too great a difference between the sizes. Thus, in a mechanic's shop, there should be tapping and drilling gauges arranged in order, so as to enable the work to be done quickly and with absolute certainty. One of the great and important advances made in workshops is this system of working to gauge, and thus making perhaps a thousand machines, any one part of which will fit a similar part of any other. It is the same with screw bolts and nuts, of which a certain size always has the same pitch of thread, so that if you lose a $\frac{1}{2}$in. bolt you can take any other of that size, and it will screw into the same hole as if specially made for it. This system of screw bolts is due to Sir Joseph Whitworth, one of the first mechanics of the day.

The Slide Rest for Metal Turuing will be found of great service to turners in metal. The tool is held (on the work) by a clamp attached to a plate sliding smoothly and accurately between guides, which compel it to travel always in a right line. In the slide rest, this sliding plate is fitted between guides attached to a similar plate moving at right angles to it, also between parallel guides. A tool, therefore, clamped to the top plate must needs travel to and fro in a right line either exactly parallel to the lathe bed on which the rest is fixed, or at right angles to it. This traverse is effected in both cases by a screw, which gives a very even motion. All we have to do is to set the tool correctly, start at one end of the work, and turning the handle of the long screw, we shall see the tool travelling steadily along, detaching a neat shaving, and soon reducing the bar to perfect truth. With face work we have to use the cross slide to advance the tool, and we set it up to cut with the other; but the operation is the same. A common form of slide rest is shown here, Fig. 10; but M, the tenon which fits between the bearers or bed of the lathe, should be placed nearer to the farthest end, and not in the middle as here shown. The two slides, M N, and X, are, however, correctly shown with the tool holder, A. The plate, or turntable, G, allows the top to be swivelled round when conical work is desired instead of parallel. The tool holder is now generally of a lighter description than represented in this figure, which, however, gives a pattern used for heavy work. It is not worth while to draw, however, a second rest, as I merely wish to show the general construction before proceeding with details of its various uses.

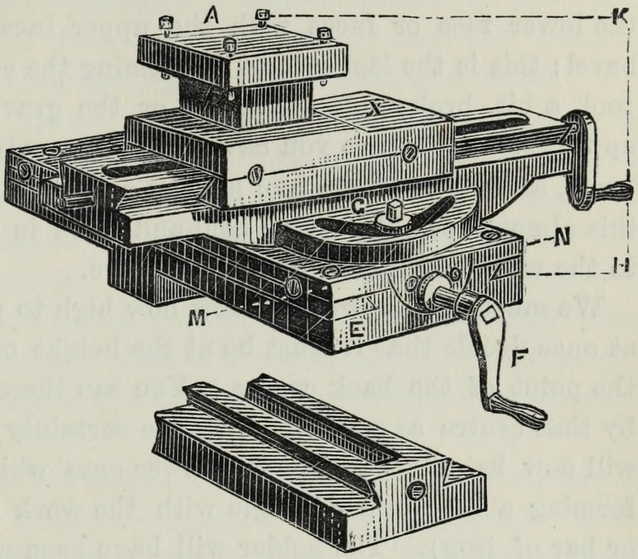


Fig. 10.—Slide Rest for Metal Turning.

Nothing appears simpler—nothing easier, but, like all mechanical work, slide rest turning needs knowledge and practice. The tool must not only be well and accurately ground, but placed with even greater accuracy to bring its edge into the best position. It may scrape and not cut—it may dig in and spoil the work. It may take one shaving off well, and at the very next traverse ruin the job. It is only partially that I can explain here the essentials for satisfactory work with fixed tools, which, once placed, remember, must retain their position, unlike hand tools, the position of which may at any moment be altered and adjusted if not working as they ought to do. Slide rest tools have two or three faces, and generally have two cutting edges. Even a round-end tool may be considered as having an edge each side of the central point, but these have been eased off so as to form a single curved surface.

The commonest of the slide rest tools are these round ended ones, and point or diamond tools, like a graver with its bevel uppermost. But the best tools to use are little bits of straight steel bar held in a proper holder, and ground to suit the work. For all amateur work their superiority is beyond question, especially as they can, and ought always to, be home made. But whether the solid ones or these are used, and whatever may be their special forms, we may consider them as having one or two cutting edges, and that these are formed by the meeting of the lower face or faces with the upper face, usually termed the upper bevel; this is the last ground in forming the edges. Let us take a sample tool, a bit broken off a graver, or the graver itself set on end, bevel upwards. Now, here you have only one newly ground face, viz., the top bevel, and many of the tool holders are made to hold just such a tool as this almost upright. If so held and fixed in the slide rest and advanced to the work end-on, it will cut a groove.

We must first, however, know how high to place its point, and you may at once decide that it must be at the height of centres, *i.e.*, the height of the point of the back centre. You can therefore set it up in the holder by that centre as a guide, with the certainty of its being correct. You will now have two faces—the lower ones which meet at the point, each forming a certain fixed angle with the work (suppose it a mere cylinder or bar of iron). The holder will have been made to bring the tool, as I have said, nearly upright, so that each face will be at a small angle to the surface of the work. Still you can alter this at the grindstone if you please, but we need not at present consider this necessary. If now you bring the tool to the right hand end of the bar, advancing it to take a light cut, and work it along by the slide rest screw from right to left, it ought to cut a tolerably clean shaving, but it will do this much better if you do not set the tool precisely "end-on," but turn it round a little so that the right hand edge shall be more parallel to the bar. If, when so placed, it does not appear to act well, you must examine it in relation to the following particulars :

1. Is it placed on the line of centres as it ought to be ?
2. Is the edge (or edges) sharpened to suit the metal ?
3. Is the clearance too great or not enough, *i.e.*, does the point or either face rub, which is the case with too little clearance, or is the clearance too great, causing the action of the tool to be more scrape than cut ? If either of the latter faults exist, and you are using a cutter holder, it is faulty if it is intended so to hold the little cutters that they shall not need grinding except on the top. It is more likely that the clearance is too great than the contrary ; and, if so, go to the grindstone and correct it so as to make the front face more upright, because it is evident that the cutter bar holds the little tools at too great an angle, not sufficiently upright. For these front planes, like the face of a hand

tool, should make a very small angle with the work, just enough to keep them from rubbing. The best cutter bars (tool holders) are made to necessitate grinding three faces, and then you can give what clearance you please, besides making the cutting edges and all angles such as experience may show to be the best.

The second suggested fault—the angle of edge unsuitable for the metal—refers to the fact that you want sharper edges for steel and wrought iron than for cast metal, and blunter edges for brass and gun metal. You make sharper edges on a graver, or a tool of the same character, by grinding the bevel more slanting, or at a smaller angle with the front line; and an obtuser one is made by grinding it off at a greater angle, so as to make a smaller diamond-shaped face. If the tool is one with a round end, a round bar ground off at an angle, similarly to a graver, giving an ellipse-shaped upper bevel, the same faults may exist, and must be remedied in the same manner. This is a favourite tool with very many mechanics, and will make nice work either on brass or iron if well ground and carefully placed.

Inside tools are subject to the same conditions, except that they may be placed a little higher, and often have greater clearance given to them, being more liable to rub. Lighter cuts, too, are taken, because boring or hollowing out work needs more power than outside turning or traversing. Face work is turned from the outside towards the centre, *i.e.*, it is the proper way to do it, but you may use either a round or point tool end-on in either direction, and this method is very commonly adopted to save the loss of time in running back the tool without letting it cut. You will find wrought metal the easiest to cut, and will obtain from it nice clean shavings. Cast metal is crystallized, as you may see by breaking it, and hence you will not get continuous shavings, but chips and dust, and it is harder and less pleasant to work, except by the file. There is now, however, a cast iron which is annealed and softened, and brought to a state known as malleable. This works very pleasantly under the file or turning tool.

I must now conclude lathe work, except so much as will have to be given in detail when I treat of the construction of special toys of a mechanical character.

CHAPTER V.

TOOL GRINDING.

UNLESS tools are well and keenly sharpened satisfactory work is impossible. Much of the difference between professional and amateur work arises from the bluntness of the tools of the latter. No mortised and tenoned joint can be made to fit closely if the work is not cleanly cut by a sharp chisel; and planed surfaces, if badly done, are more unsightly than if left rough from the saw.

Various contrivances for holding a tool securely during the operation of grinding have been devised, and I may notice the undeniable fact that I never saw them in use among workmen. It is indeed a mistake to rely upon what are, at best, questionable devices, when, by patient practice, we can gain that skill which will not fail us in the time of need. A simple toolrest—a mere bar of iron parallel to the face of the stone, may be a help in steadying a tool; but even this is seldom to be seen in the carpenter's shop, its absence proving that it is not a necessity. But there are necessaries in tool grinding always to be found among practical mechanics which are too often wanting among amateurs, and these are patience and determination. Grinding tools is a laborious and disagreeable operation, which is sure to be avoided as long as possible, and is terribly scamped by amateurs when it can be no longer delayed. If, however, it must be done, let it be done thoroughly, or the labour bestowed will be entirely thrown away.

The main object of grinding is to produce a bevel on one side or both of a tool blade, in order to reduce the metal to a thin cutting edge. This bevel must not be too short, or the angle of edge will not be small enough; it should, therefore, be carried well up the blade, so as to present a broad surface. In a perfectly new chisel or plane the grinding will be found insufficient, because tools with keen edges cannot be kept in stock. They would endanger the hands of the shopmen, and would also get damaged and notched by contact with each other. Hence a new tool must be ground before use, and the bevel already formed extended. But if you examine the surface that has been ground by the workman you will see how flat and even it is; the upper part forms a straight line across the blade, and the whole is quite flat, even, and true. This is what you have to aim at, and when you commence to be your own grinder you will be disgusted to notice how you have spoilt the even bevel which the tool once had. Instead of one bevel you have produced several, lying at all sorts of angles with each other. This arises from not holding the tool steadily upon the stone.

To get an even bevel the stone must itself be absolutely true, and not wobble from side to side. You can now buy, at a comparatively low price, excellent grindstones turned quite true upon the face, and worked by a treadle; or you can buy, for a few shillings, an unmounted stone, and fit it up, or have a frame made by a carpenter. In either case have it fitted with a treadle, so as to render yourself independent of assistance; and have a nice fine Bilstone, not a Yorkshire grit, which is more fit for coarse work. I do not think you will gain by buying the small 5in. or 6in. stones now to be had in metal troughs; they do for chisels and turning tools, but are of no use when an axe or plane iron has to be sharpened. A stone 18in. diameter to 2ft. at the most will do all you need. Probably the former size will suffice, but one less than 18in. has hardly weight enough to make it act as its own fly wheel. Any small stone to be used for plane irons would need a fly wheel on the same axis to give it the necessary impetus, and such a fly wheel would be often found terribly in the way of the arms and elbows. Moreover, you require a tolerably large stone to produce a sufficiently flat bevel, although a slightly hollow one is no great disadvantage. Have, therefore, a good sized stone nicely mounted as the first essential of good work, and having once obtained such use it well.

Now, to use it well is not to allow one side to lie constantly in the water, which will rapidly soften it, and of course cause it to wear faster than the other, thus rendering the stone untrue. Hence, although you need a water trough to catch the water from the drip-can placed above it, there should be a pipe below to carry it off at once into a bucket or drain, which will also remove the muddy silt that is so often allowed to accumulate in the trough until it well nigh prevents the stone turning round. This again is an essential lesson in cleanliness, which must by no means be neglected in a mechanic's workshop.

Supposing the grindstone thus mounted to run truly, the next consideration is the way to hold the tool. This must be held rigidly in one place, *i.e.*, at the same level, merely being traversed from side to side to prevent it wearing the stone unevenly, especially if the tool be a narrow one like a mortice chisel, which, if held quite still, will cut a channel, and spoil the face of the stone. Now, if you grind with the stone running away from the edge of the tool, and do not hold it firmly in position, the former will seem to lay hold of it and drag it away to a higher position. This is what you have to resist, and the best way to do so is to hold the elbows firmly against the sides, which affords a very secure grip indeed. This is not the orthodox way to run the stone, which should always turn towards the edge of the tool, although it would naturally appear the wrong way to use it. But to turn the other way is to produce a wire edge, which is difficult to remove, and no workman would grind thus, unless it were a narrow tool, liable to groove the stone.

The tendency of the stone, therefore, will generally be to drag down the tool, the danger being that if you let it do so it will dig in and cut out a notch, tumble into the trough, and give you a practical illustration of the art of knuckle grinding. But it is easier to resist this tendency to drag the tool towards you, and you will soon learn to hold it steadily and level (for here is another difficulty). If not held level and square across the stone, the bevel will be broader at one part than the other, and the edge of the tool will slant, so that (if a plane iron) it cannot be placed true with the sole of the tool. If only for a moment you let the tool have its own way, you will find that a fresh surface has been ground out of the general plane. Thus it is evident that to grind a tool well needs practice, and a pair of good strong arms, and the art cannot be learnt in a day. Being moreover a tiresome job, one naturally feels disposed to shirk it, which means grinding a smaller bevel, and, of course, obtaining a blunter edge.

In addition to the fault of unevenness of bevel, a very common one is a rounded surface instead of a flat or hollow one. This results generally from paying more attention to the edge than to the entire bevel. Let the extreme edge take care of itself, and concentrate the attention upon the flat surface of the bevel, especially the middle of it, and grind till you observe that the edge has actually come down upon the face of the stone, proving the work done. All success depends upon the rigid hold upon the tool keeping it steadily at one level. The pressure need not be excessive, and, although it may take longer, the labour involved will be less if only a moderate pressure is kept up. Sway the body from side to side (not the arms alone) in order to traverse the tool across the face of the stone, and a little careful practice will insure success.

After awhile it will be found easy to grind with the arms more free; but I have found, practically, the way I have described the surest and safest for beginners.

To test the correctness of the edge, try it with a square, especially if it be a plane iron, and if it be ground slanting instead of square to the sides, you must set to work again. Knowing this penalty to be in prospect for careless work, you will be wise to test the tool once or twice as you proceed.

Assuming that the grinding is satisfactory, you now have to set the edge on an oilstone to make it smooth and keen. In this operation, which looks a deal easier than it is, the danger of rounding the bevel steps in. What you have to aim at is to produce a new narrow, but decided, bevel at a slightly greater angle than that obtained by grinding, and you must not round it off into the other. If you are a novice your success is highly problematical. I must pre-suppose a good oilstone, Arkansas or Washita, the first being the best, level and clean, and with a few drops of clean oil or paraffin upon it. Set it on the bench with one end towards you, or nearly so, as the movement of the tool will be to and fro from end to end of the stone. Grip the iron firmly in the left hand, and place the other hand over it, grasping it, but with the first three fingers pointing downwards towards the edge of the tool—a position that gives a good steady hold—and laying the iron upon the stone at a rather larger angle than that of the bevel, rub it steadily a few times to and fro. By "larger angle" I mean a little more upright than lying flat upon the bevel. In pushing the iron from you, it is necessary to raise it to a slightly more upright position, and to depress it as you draw it back again, because the natural movement of the arms, unless thus counteracted, would lower the iron as it recedes, and thus tend to round off the bevel—the error already alluded to. The movement will become quite easy and natural by and by, when once you know what you have to do, but it takes practice to move the arms thus horizontally, and their natural tendency is to move in an arc of a circle, of which the shoulder joints form, of course, the centre. A rounded bevel will cut, but it is not to be compared with a flat one, and is, besides, very unworkmanlike.

I shall not enter into a question here as to the proper sizes of tool angles. Let it suffice for the present to remark that for deal and other soft and fibrous wood the tools cannot be too keen, and that, therefore, the bevel must be large, *i.e.*, the tool must be ground some distance up the blade, while for hard wood it need not be quite so far ground, but must be kept sharp even at a larger angle.

Before putting the newly-ground iron in the plane, lay it quite flat upon its back on the oilstone, and pass it once or twice up and down to remove any slight burr thrown up by the stone. The top or break iron is placed low down or the contrary, according to whether the plane is to be used for rough or fine work. In a jack plane it is placed about ⅛in. from the edge, but in a trying plane or smoothing plane it must leave only a very narrow bit of the cutting iron exposed. The object of this break iron, as it is called, is to bend up the shavings sharply, so as to insure their being cut off and not split from the surface of the board. Put the irons thus clamped together into the stock with the bevel of the cutting edge below, and placing the wedge in position, tap it in lightly. Then turn the plane upside down, and take a glance along the sole (the eye at the front or forward edge), and you will see the black line of the iron, a mere line if the plane is set finely. If it projects too far, a tap with the mallet on the top or back of the stock will cause it to withdraw if you have only wedged it lightly. If the iron does not project at all, you may give it a tap to send it forward, or a blow or two on the front end of the plane. When just visible and true to the level of the sole, another tap on the wedge will secure it—but never drive the wedge too tight, or you will split out the sides and spoil the plane.

The method of grinding other tools, as chisels, is so precisely similar, as well as the mode of setting them on the oilstone, that I need not extend this chapter to treat of them separately. Practice is all that is required to make anyone a good tool sharpener.

CHAPTER VI.

SMALL CARTS AND HORSES.

Having given a description of the necessary tools and appliances called into service in toymaking, I will conclude that the amateur has provided himself with the things mentioned, and is now ready for action. I shall therefore commence by describing the manufacture of small carts and horses, these being the most simple of the toys to make.

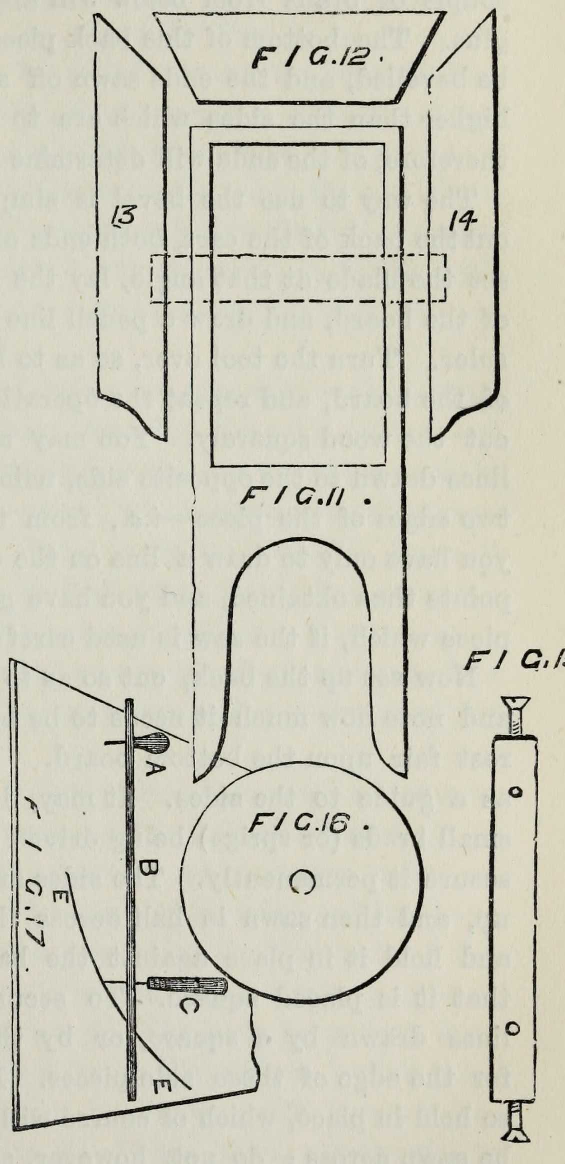
Now, to use a common form of speech, "there are carts and carts," even among toys. The penny cart is an apparently simple affair, consisting of a body with shafts cut out of the bottom board, and a pair of wheels, either on a wire axle or on a square axle of wood, about the size of a match. No nails appear anywhere, nothing but glue, sparingly used, yet these hold together marvellously, and, by the aid of a daub of paint, to hide defects of workmanship, are rendered satisfactory to the owner. These come chiefly from Germany, and yield a good profit, even at the low price at which they are sold. In our case, we may want to make a few—perhaps only one or two. But where made by the hundred the pieces composing them are cut out all alike in large numbers by small saws worked by steam, and the actual maker does nothing but glue up one after another, leaving to another workman the wheel department, and to another the painting.

For home manufacture, too, it is as well to follow the trade in preparing all parts before attempting to put any together. The bottom, of orthodox form, may be made first of a board, $\frac{1}{8}$in. to $\frac{1}{4}$in. thick, according to the intended size of the concern—$\frac{1}{8}$in. is thick enough if the cart to the end of the shafts is not to be above 6in. long. If of deal, the shafts are pretty sure to split off before long, and therefore it were better to use lime, willow, or poplar. But it is of no great importance nevertheless, toys being made to break, and deal must answer if other woods are scarce (for willow an old cricket bat will cut up into a lot of small boards). We may as well at once define the size of our cart, which for small wheels, punched out, we must make of very small dimensions; we can make larger and better afterwards. The size of such an affair, costing one penny, is as follows: Extreme length 5in., width 2in., the shafts taking up 3in. of that length, thereby reducing the body to a square. But as the back and sides are glued upon this board, and the latter has a margin of about $\frac{1}{8}$in. along each side, this gives the actual cart a little extra length in proportion, so that it is slightly oblong. The diameter of the wheels is just 1in. These can be cut out with a large gun punch, but care must be taken that the wood used is thoroughly wet to give good results, and it should not be deal or wood with open grain, but willow, alder, sycamore, or other soft close grained stuff not liable to split. This being cut into thin pieces—$\frac{1}{4}$in. thick is a good standard, or even $\frac{1}{8}$in.—should be well soaked and cut at once while the water is in it. The pieces should then be placed one on the other, and screwed up in a vice to dry; they will thus remain quite flat. Small boards split, soaked, and thus pressed, will turn out almost as flat and smooth as if planed.

Circular pieces of larger size must be cut out by means of a fret saw, the circle being first marked by compasses, but if a fret saw is not come-atable wheels of any size can be cut out by putting a bradawl through a lath, and at such a distance as will cause a circle to be described of the right size, fix a penknife blade upright in a slit made with a small chisel across the lath (*i.e.*, across the grain), so that the blade will cut when the lath is moved round the bradawl as a centre. The bradawl is then stuck upright in the thin board, and a circle described by moving the other end carrying the knife blade. After going round carefully in this way a few times the board must be turned upside down, the awl placed in the same hole, and the work completed. Rings, as well as solid pieces, can thus be made, but require great care to prevent splitting the stuff. If these are to be used as wheel rims, two of such should be glued together, with the grain of one running contrary to that of the other. The bottom board is $\frac{1}{8}$in. thick, but the sides are barely $\frac{1}{16}$in.

To reduce boards to such thin scantling you will find it necessary to have a bench with perfectly level surface; or, what will be quite as well, a well planed board of about $1\frac{1}{2}$in. thick to lie upon it and rest against the bench stop, such board having its own special stop against which to set the end of that under operation. If the bench on which you try to plane is itself uneven, good work is impossible, as the stuff used will oscillate and shift about under the plane. The vice, too, should be well made so as to shut up closely, and two screws will be far better than one.

It often happens that the boards used in toymaking, which have to be planed on the edges, are very thin, rendering it difficult to contrive any satisfactory plan for clamping or holding them on edge upon the work-bench. If the bench vice, indeed, be really well made, with the inside face accurately fitted to the front plank, any pieces, thin or thick, can be held thus; but this is by no means the general rule, especially with country made ones. In this case the better plan will often be to set the trying plane (or other plane) upon the bench bottom upwards, and to draw the thin edges along it, reversing the usual process. With such small pieces as can be easily held in the hand, there is no difficulty in this, especially if a jack or trying plane is used, nicely sharpened and finely set. All the boards of our small cart can be edged in this way. For this toy they also require to be bevelled slightly, so as to slope outwards and rest truly upon the bottom board, as the back of the cart is so shaped as to require this.



Figs. 11 to 17.—Parts of Small Cart.

I may state that in the cheaper class of toy all possible work is saved, and paint laid on thickly hides sundry and divers imperfections. In many such no bevel is made, but by dint of glue, small brads, and paint, the parts are held together, and the lack of proper fitting is duly concealed. But in papers like the present we shall give the proper mode of work and allow no scamping, as we thus get good lessons in carpentry. Cut out, then, first the lower board and shafts (Fig. 11). You are not tied to the dimensions given, but may make it of any size, only a larger cart will need to be put together with brads, or brads and glue in combination, whereas, a small one of 6in. from end to end will hold well enough with glue alone. The smaller sized one you may, moreover, cut with a knife if you have not a fret saw, but the larger will need a key hole saw or fret saw to shape the bottom and shafts. Having cut out this (planed always before being shaped), make the back (Fig. 12, p. 45), using, if possible, thicker wood than that from which the sides are cut, so as to allow the latter to be more firmly glued or attached to it by nails. A couple of brads from below will also secure the bottom and assist the glue. The bottom of this back piece, which should lean outwards, must be bevelled, and the ends sawn off at an angle. It should stand a little higher than the sides which are to be nailed or glued to it. The slope therefore, of the ends will determine that of the sides.

The way to use the bevel is simple enough. For instance, in cutting out the back of the cart, both ends of which must slope at the same angle, set the blade at that angle, lay the handle so as to rest against the edge of the board, and draw a pencil line along by the edge of the blade as a ruler. Turn the tool over, so as to bring the blade near the opposite end of the board, and repeat the operation ; cut at these lines, taking care to cut the wood squarely. You may absolutely insure this by carrying the lines drawn to the opposite side, using a square to draw the line across the two edges of the piece—*i.e.*, from the ends of the sloping lines. Then you have only to draw a line on the other side of the board from the two points thus obtained, and you have guides for the saw on both sides of the piece which, if the saw is used carefully, must insure a correct cut.

Now set up the back, cut so as to stand at the desired slope outwards, and note how much it needs to be bevelled off at the bottom in order to rest fair upon the bottom board. Plane to this angle, and it will serve as a guide to the sides. It may, in fact, be now glued and set up, two small brads (or sprigs) being driven through the bottom board into it to secure it permanently. The sides are to be first cut in one piece, planed up, and then sawn in half across the middle. Take one of these pieces and hold it in place against the back already fixed, taking great care that it is placed square. To secure this, mark on the bottom board lines drawn by a square, or by the edge of a square card, as guides for the edge of these side pieces. Mark these by the back board when so held in place, which of course will give the slope at which they are to be sawn across ; do not, however, saw at this line, but a little beyond it at the same angle, because these lines will serve as a guide for replacing the sides when glued, and in addition to this they are to extend a little beyond the back, say $\frac{1}{16}$in., which projecting bit is then often slightly ornamented by a few scallops cut with a gouge. The length being also similarly marked, the little boards may be cut off both to the same length and angle, and shaped to suit the taste. When held in place against the back, the degree of bevel required at the lower edge is to be noted, and a touch or two of the plane given. This will complete the shaping process, and the parts may be glued and left to dry.

The axle (Fig. 15, p. 45) is a squared piece of wood, attached underneath the cart bottom by glue, and further secured by brads driven in the two places marked. The wheels, plain discs in this case (Fig. 16, p. 45), run upon two common wood screws, as shown in Fig. 15, p. 45. The axle must clear the sides well. It is dotted across the cart in Fig. 11, p. 45, to show this. Fig. 17, p. 45, illustrates the mode of cutting out circular pieces with a knife, already alluded to ; A is an awl passed through the lath B, which turns about it as a centre; C is the pen blade, also stuck through the lath ; and E, E a trace of the circle it is supposed to be cutting. The cart is not represented put together, as this is quite unnecessary; all the different parts are supposed to be lying flat on the bench ready to be glued up.

Bevels of different angles, instead of being exactly alike—the bottom out of square—one side attached nearer the edge than the other—and any similarly crooked and inaccurate fitting, are the faults most commonly seen, producing dissatisfaction with the work, which more care will always enable the young carpenter to avoid. Paint is always allowable, but will not conceal defects of the kind named, and all parts should be made true and even, and of smooth surface before paint is applied. For the latter bright colours are best—say, a nice bright green picked out with red. The wheels green, and red stripes painted on as representing spokes, but the green must first be quite dry.

No doubt a cart without a horse is but half a toy, yet it appears to me that the wooden animal has not many points worthy of notice. In some respects at any rate his form is of a stereotyped character, unless we take, as a specimen of the better breed, the horse whose body and legs have more pretence to an imitation of the genuine animal. The body of the usual toy horse is, of course, lathe work, the legs ditto, or merely split or sawn stuff, according to the maker's fancy. The body bears just thus much resemblance to a horse's that it rises at the withers and is supported by four legs ; but no child, I suppose, looks a gift horse in the mouth or elsewhere, in order to criticise it. Turn, then, a body of any desired size and shape, not deviating too much from the orthodox form, and plane this below to a flat surface, in which fix the legs, and so far, at any rate, your work will be satisfactorily done. As to material it is probable that a coat of paint will conceal it, but lime or willow will be best, as it will not so readily split, and for the head especially deal is almost useless, and beech, ash, or any wood of that kind cut and planed to ¼in. or ½in., according to the proposed size of the animal, should be substituted, or the horse will soon be minus its nose or head. This part, head and neck, should be cut out with a turn saw or fret saw to lines previously drawn, but it can be managed with a tenon or hand saw by cutting out a triangular piece so as to leave the head and neck clear, and finishing with chisel, spokeshave, and rasp. A turn saw or fret saw is, however, so far the better tool, and is so serviceable for other work that it ought to be procured, and the former is very inexpensive. The neck squared off neatly below, where it is to join the body, is, or ought to be, let into a groove or channel sawn and chiselled out to fit it tightly. Into this it must be glued, which will secure it without nails if the fitting is as it should be.

Some toy horses of more life-like form than those to which I have alluded, cannot be made by the amateur. I refer to those constructed of a wooden foundation, with plaster of Paris, or some such composition laid on and formed in a mould. Such are the horses sold in wooden stables, which are very neatly made, but easily broken, and are not fit for home construction. Similarly there are well moulded horses of papier maché, or paper pounded in water to a pulp, and then moulded, dried, and coloured. But in the Swiss valleys horses are often made of some kind of beautiful white pine, carved into shape with simple tools and left totally unpainted.

To try and carve in this way is a bit of toymaking far better worth the labour than merely to reproduce the kind of shapeless horse found at our toy shops. The main outline must be sawn out with a small turn saw, and the body then finished by carving tools, or sharp knife. In willow this is not very difficult, even if the legs and body are made of one piece, but very often this is not the case, in order to get the grain to run lengthwise down the legs. These must then be roughly shaped, with a short peg or tenon left for insertion into the body, and after being glued in they must be finished with the other parts, and by good fitting and a little management in carving it will be scarcely possible to see the line of junction. At all events, the more correctly shaped horse, even if it has to be painted, should be attempted by anyone who is fairly *au fait* at using tools, although, as a toy for very young children, who will probably break it very speedily, the old-fashioned turned body and stereotyped form will suffice. One of these horses will take about half an hour to make—a carved one two hours or more.

CHAPTER VII.

WHEELS FOR LARGE CARTS, &c.

In the construction of large wheels it is, as before stated, almost impossible to get on without a lathe. I was not, however, able in Chapter IV. to carry the reader through more than a course of simple turning sufficient for toymaking. Should the reader wish for still fuller particulars, I must refer him to that little volume, "Turning for Amateurs," which gives every detail of such work, and initiates into the mysteries of chucks and tools, rests and slide rests, and the actual operations of the turner.

Mount upon a taper screw chuck a piece of board, either square or roughly rounded by sawing off the corners, and turn it true on the edge with a gouge. Both sides should first be planed, and the thickness may be $\frac{1}{4}$in., $\frac{1}{2}$in., or $\frac{3}{4}$in., according to the proposed size and nature of the wheel to be made, for there are two or three modes of work different to that of the cheap toy cart wheels, and very much better in every way. The $\frac{3}{4}$in. stuff will make strong wheels, fit for a good-sized cart or barrow.

Having made the stuff true on the edge, bring the rest in front of it, and present a sharp parting tool to the face of the work; with this detach a ring of sufficient breadth to form the felloe or outside hoop of the desired wheel. We will suppose it 4in. or 5in. in diameter; detach a second ring, and leave the rest to serve as a solid wheel for some smaller cart. You have now to bore this to receive the spokes. Divide it into the requisite number of parts, six or eight, or thereabout, which you can do very easily by cutting a strip of paper that will just go round it and meet, and, doubling the paper the requisite number of times, measure off and mark with a pencil the place and direction of these holes, which must be bored radially, or towards what was the centre before it was cut out. You will get this right if you lay the ring on its side, *i.e.*, flat down on the table, and rule across from one division to that exactly opposite; this will give the proper position of each hole. Now to bore the holes, which should be about the size of a quill or small pencil, great care will have to be exercised, but the best way by a very long degree will be to drill them, and there is no appliance more necessary in a lathe, small or large, than a drill chuck and set of twist drills or fluted drills, or at least plain drills, such as any smith can make. Anyhow, have some drills sooner or later, but if not in stock, never mind, we can get on without them with a brace and small nose bit or quill bit, or even with gimlets, but these are ticklish customers, much given to splitting deal, and the only way is to use first a small one and then follow by larger ones, but a quill bit, which is like a small gouge, is always a safe tool for this sort of work.

It is easy to make a square hole chuck of a bit of boxwood to take any one of the ordinary set of carpenter's brace bits, or the twist drill with square shanks made for brace or for the lathe. Drilling in the lathe is sure work if you start well; suppose you have marked the wheel rim for six, eight, or any even number of spokes, the drill point is to be placed on one mark and the point of the back poppit on the opposite one. Then, advancing the back centre by its screw, you cause the drill to penetrate, and in a second the hole is made. Then reverse the wheel and put the back centre point in the hole already made, and drill No. 2 and so on all round. We need not at present dish the wheels, *i.e.*, make the set of spokes slant outwards, but we can attend to it by and by. It will now be necessary to make the nave or central part into which the other end of the spokes are to be fitted, and which runs upon the axle, or is attached to it.

Railway trucks are fitted in the latter way, carts and waggons in the former. It is best to turn at least two of them at once, or to turn up a cylinder of wood—beech or ash by preference—and to divide it with a parting tool into several, first notching the piece right and left with the chisel; when cut at the place of these notches the pieces will then be shaped up, or bevelled each way sufficiently; or, for better appearance, they can be neatly rounded off at each end. After these are all cut off, bore for the axle and drill for spokes, using the same drill with which the rim was bored, and working in the same way. The spokes need not be turned, but, of course, *may* be so made, and will look all the better if they are tapered each way so as to be a little larger in the middle than at the ends.

Now, there are two or three ways of getting the spokes into place. One is to glue them into the nave, and then saw the rim with a very fine saw into two or three pieces, making the cuts radial, as the holes were made, *i.e.*, tending to the centre. If cut into three with a fine saw, like a fret saw, you can put the parts together, inserting the spokes as you do so, and giving a touch of glue to each joint, and here and there to the spokes (you need not glue them all), and you will not be able to detect the fact that the wheel is not truly round, so very slight will the deviation be. Of course, care must be taken to keep the nave central, but this is easy if you mark a spoke here and there (three will do) and insert them at the mark so made. If three are right the others will be so, unless you mark three that are close together. The ends of the spokes should fit their holes well, but just so that they can be adjusted easily. This is one, and, perhaps, the best mode of finishing a wheel.

Another, which does not necessitate dividing the ring into sections, is to cut the spokes just long enough to go within the rim when in place in the nave, and then to affix the rim by a brad into each spoke. In this case, instead of drilling the rim with holes to admit one end of the spoke, mark and bore with an awl only, and with a smaller awl inserted in each hole bore also into each spoke, which should be left large enough to receive a small brad without danger of splitting. A large number of toy wheels are thus put together, but these have only thin bent stuff for the rim or felloe, instead of turned rims. This plan is less trouble, and can be more quickly carried out, especially if, as often happens, only three or four spokes out of six or eight are nailed.

A third plan is to drill for spokes and place them in order in the nave, but loosely, so that they hang down somewhat when the nave is held up. Then, placing them inside the rim, and guiding each spoke to its destination, they will enter their respective holes, when, by pressing down the nave, the spokes, needing more room than they did in their first position, are forced outwards.

I have illustrated most of these details, in Fig. 18, p. 52, to render the various methods easy to understand, and will now pass on to wheels of a different kind, also illustrated, as solid wheels. Some of these may be made highly ornamental, and even when plain they are very capital wheels for toys, especially suitable for engines and railway trucks. Each consists of five pieces made and glued up as follows: The felloe or rim is turned as in the previous case, but the stuff used need not be so thick. It may vary from ½in. to ¾in., according to size. Cut out two rings, as before, of precisely the same size, taking care to cut them squarely with a sharp tool that the outside may be neat and smooth. First, therefore, cut off the superfluous stuff, leaving a round disc, and then with a sharp gouge finish its edge neatly, but square, not rounded or moulded. Then cut again with the parting tool, so as to leave a ring about half an inch wide. Cut the second exactly like it, and set aside the pair. Now turn a disc of much thinner wood, thin mahogany or hard wood by preference, such as is sold for fret saw work. This disc must be exactly the size of the rings (outside measure) and must be bored centrally for an axle. The rings are to be glued one on each side of this disc, which is to stand in place of spokes, so as to form together a solid truck wheel with a projecting rim. The nave, turned as before, is to be marked in the lathe and sawn across into two parts, one of which is to be glued centrally on each side of the main disc, the two together thus forming the entire nave.

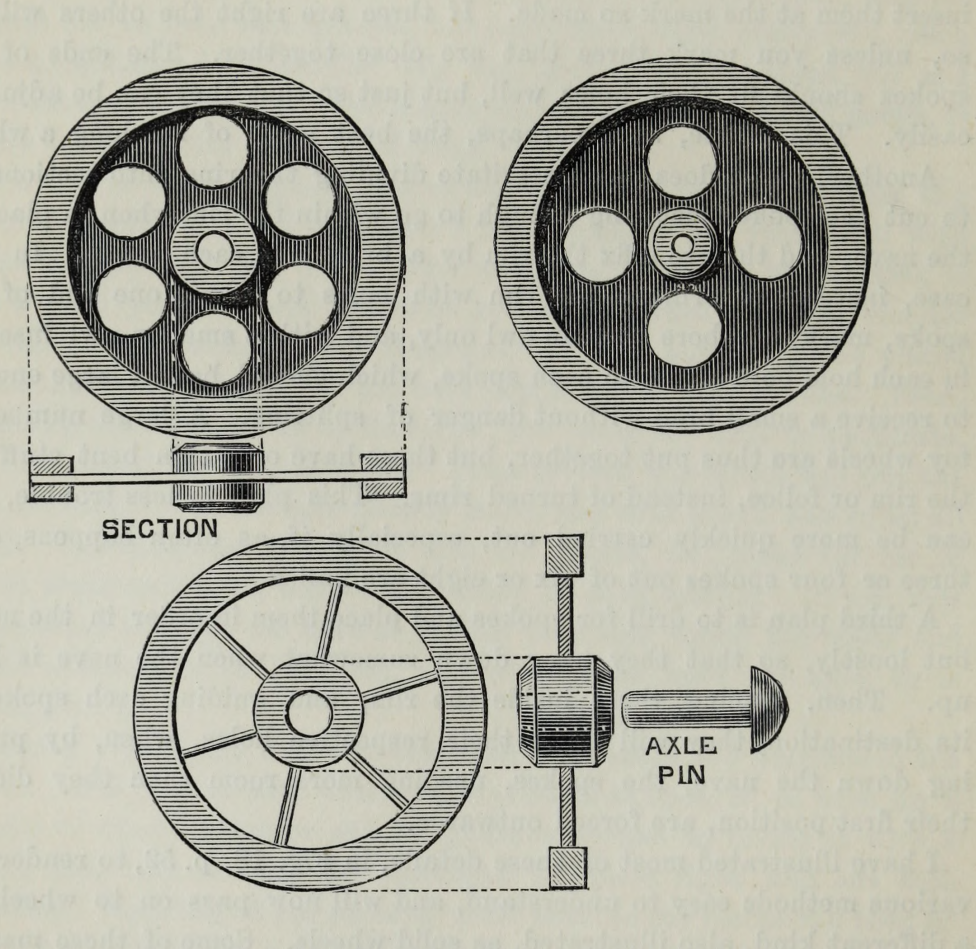


Fig. 18.—Solid and Spoke Wheels.

If neatly made and polished, I know of no wheel that looks neater than this, but it should have a tin band or tyre to hide the edge and conceal the secret of its formation. To vary its appearance and render it more ornamental, the mahogany disc can be pierced with a fret saw, or even with a centrebit, but in using the latter, which must be well sharpened, the hole must be bored half from each side, the wood being turned over as soon as ever the point of the tool is seen to have penetrated. If this is not done, one side of the hole will have a rough and jagged edge. Even with this precaution the hole will require finishing with a half round file and glass paper to render it quite smooth. Of course, the fret saw is a superior tool to the centrebit, enabling any shaped pieces to be cut out, instead of a merely circular one. Here again the illustrations given will assist the reader in this work.

A more common, though not by any means the best, method of wheel-making, is to turn a nave, insert spokes of equal length, and then form a rim out of a bit of thin wood bent round, secured to the end of the spokes by small brads and joined with a half lap or splice, generally of a very rough description. This makes a decent wheel, if the hoop is not too thin and the splice is nicely fitted, but that is all I can say in its favour. The wood used should be willow or ash, and this, too, must be steamed or steeped in hot water to allow it to be bent without danger. It is not very easy to plane a very thin bit of stuff, using the bench stop, as the material will, in all likelihood, double up and break. The best way is to put a brad or bradawl through the right-hand end, pinning it to the bench, and not using the stop at all; the act of planing then tends only to stretch the piece, and cannot bend it, and it can be made as thin as one may desire. It should not only be wet or soaked in order to bend it, but nailed on the spokes in this condition, and when dry it will have no tendency to spring open. Moreover, there is less chance of the wood splitting when the brads are inserted. Nevertheless, an awl should be used, and I prefer what is known as a birdcage maker's awl, which is three sided, and very suitable for all work of this kind. A small one, nevertheless, of the ordinary kind will answer, but the chisel-like end must always first be placed to cut across the grain. It will then make its way without danger of splitting the wood. These wheels should be banded with a strip of tin, painted black to imitate an iron tyre.

Wire has become very common for wheel spokes from the bicycle to the toy cart. For the latter it has this convenience, that it needs no preparation except straightening, and it will at once pass into a hole made by a bradawl, precluding the necessity for fitting. It is also used not only for spokes, but for axles, because of the ease with which it can be thus applied. To fix it in the boss or nave of the wheel, so that it shall turn with it, it is merely flattened by a blow or two of a hammer, and then inserted in the hole made for it, which must only allow it to enter tightly.

When it is driven in thus the nave will be quite secure, and the wire axle can run either in two little wire eyes or staples driven into the wood underneath, or put through holes in wooden blocks glued on to receive it. This is a very simple and easy method of making and attaching wheels of toy carts; but it is not quite the best quality of work, and ought not to be used except for the more common class of toys.

CHAPTER VIII.

LARGE CARTS AND WAGGONS.

To make a cart which shall be a close imitation of the real thing—strong, well fitted, and of good appearance—we must have wood of good quality, not less than $\frac{3}{8}$in. thick when planed, and we shall want, not deal only, but a small quantity of oak, mahogany, or similar wood, harder and darker than deal, to give greater finish and make a handsomer cart. The body will consist of three boards permanently attached to each other, the tail board or back being a separate piece to take off and on at pleasure. Of dimensions I need still say nothing, because it is a matter of no real importance.

The first consideration is the main body of the cart, which is to be of deal, nicely planed and kept as clean as possible. This had better be put together with brads, taking care to keep it true and even. The bottom of the cart is to be oblong, rather longer than it is wide, but with square corners. A (Fig. 19, p. 56) represents this, the shaded parts being the side and front boards; B, again, is the bottom; C, the front, put on to splay outwards, as the sides are also to do. Thus far there is nothing peculiar in the mode of construction, which is like the cart first described, except that the shafts are not now part of the bottom board. They may, nevertheless, be so if preferred, and will be, of course, easier to make. I shall, however, in this case treat them as separate.

After the body of the cart has been nailed up, some strips of mahogany or oak are to be planed up to a width of $\frac{1}{4}$in. or so, according to the size of the cart, and glued on the outside at the places marked 1, 2, 3, 4, 5, being neatly fitted where they meet in the angles. These are meant to imitate the main frame of a real cart, to which the boards are nailed. They look as well as if really framed together, and give an appearance of reality to the toy. Mahogany will look the best, but oak is a nice wood for the purpose, and when varnished will be quite satisfactory.

Plane up all the strips carefully to the same width and thickness. The best way is to plane a strip long enough for all the frame on one side and then to cut it up in lengths.

Before being finally glued on, each little bit should be bevelled or hollowed out to a chamfer, as at D, except where it joins the piece next to it. These chamfers should be neat and finished up sharply with the penknife, aided by a file. Sand paper should be sparingly used, because it takes off the sharpness of the edges, thereby, to a great extent, spoiling the appearance. If the cart is like E the bars there shown will suffice. But if the sides are deeper and the cart of a squarer form, like a miller's cart, the framing (D) will look better, by which the sides will seem to be divided into several panels. The whole beauty will, however, be spoilt if the square parts are not quite closely fitted, as the deception will be at once apparent.

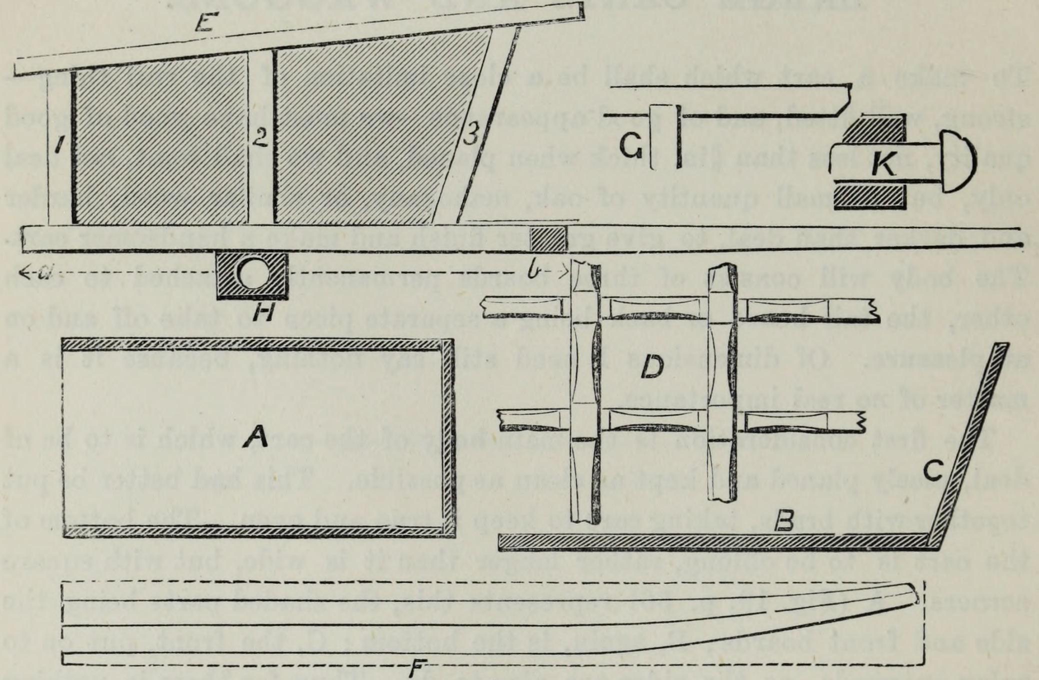


Fig. 19.—Large Cart.

We now come to the shafts. Between *a* and *b* these are planed up quite square, and are thence to be rounded off and hollowed out to imitate those of a real cart. As these should be shaped out to a somewhat curved form, they require to be cut, as shown at F, out of a piece of board wide enough to allow of this curve—such a piece as is sketched. To get both exactly alike, cut out a pattern in card, and work each shaft exactly to fit it. Each is then to be glued to the bottom of the cart, as at E, and still further secured by a brad or two driven into the shafts through the bottom board, or by two small screws in each. But, before doing this, notch each shaft, as at G, to let in neatly a cross bar at the part *b* of Fig. E, from one shaft to the other. This must be finally fitted after the shafts are attached. Secure by glue or by a brad. The crossbar is to be the same size as the squared part of the shafts. Upon and above this will be glued a flat board for a foot board. The squared bar for the axle (of oak or mahogany) is the next part to make. It is to be glued under the shafts and body of the cart, as seen in Fig. 19, a hole being bored in each end to receive the turned mushroom-shaped piece K, there shown in section fitted into the main axle. This is put through the wheel nave and glued in, which is the best way to mount the wheels of a toy cart of the kind. Take care that H is long enough to clear the splayed out sides of the cart, so as to prevent the wheels touching them.

We have not added the flat board or rail round the edge of the cart, nor have we made what I think are known as harvest-raves, the independent frames which can be put on to extend the carrying powers of a cart when hay or corn is to be carried, and which can be removed at pleasure. We will begin with the ordinary edge-boards. These are supported in a real cart upon iron brackets attached at intervals to the sideboards or to the framing, and also frequently to the front as well, to form a seat for the driver and for other purposes. All this, as shown in Fig. 20, give opportunities for metal fittings of wire and tin painted black. A, shows a bracket of twisted wire or

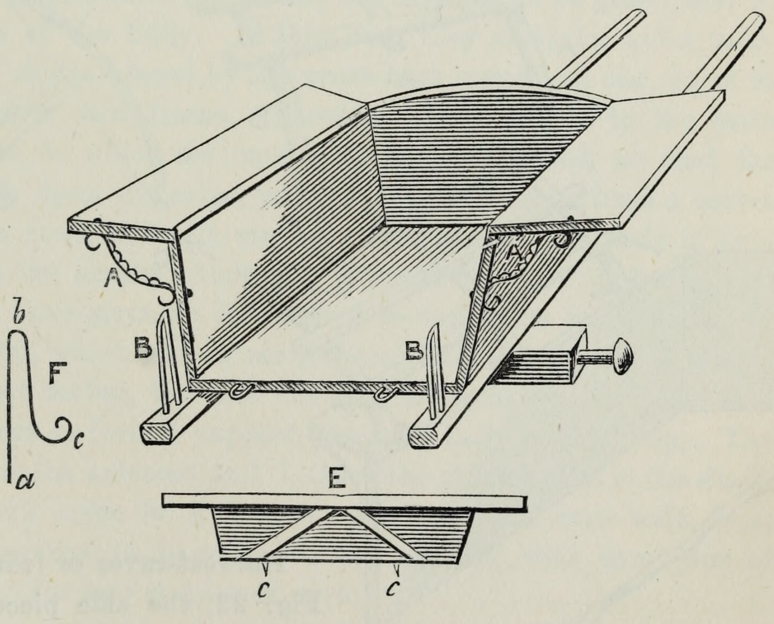


Fig. 20.—Farm Cart.

tin. You can flatten the wire and twist it when hot, leaving a flat bit at each end for the tack to attach it by, or still better, for a little wire bolt and nut. To make the tail board you want two upright pieces driven into the ends of the wood forming the shafts, seen at D, Fig. 21, the tail board being cut out like E, and dropping in behind these bits of wire.

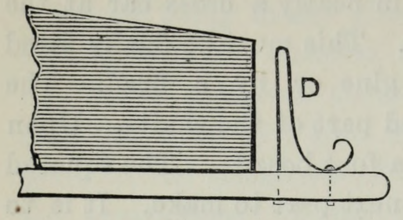


Fig. 21.—Tail Board Support.

Another way to make these upright supports is to bend the wire like F, or like *a*, *b*, *c*, pointing it at *a* to go into the wood, and flattening it at *c* to drill it for a small wire nail. At *c*, *c* of the tail board are two wire pins to go into wire staples or directly into the bottom board. If a high tail board is preferred, it may be put on with wire hinges, to fall down, and can be fastened up when desired by small hooks. By using stout wire and heating it, you can flatten and twist and bend or shape it as you like, and imitate the real iron work without difficulty.

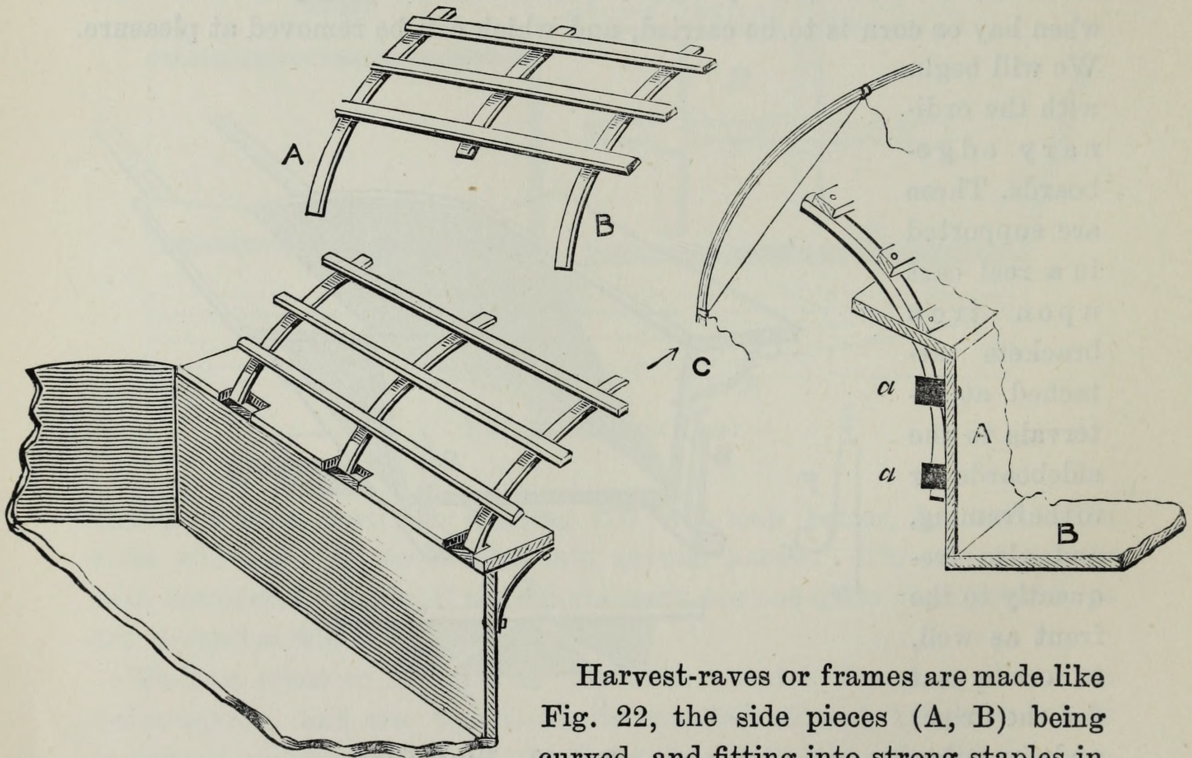


Fig. 22.—Harvest-raves.

Harvest-raves or frames are made like Fig. 22, the side pieces (A, B) being curved, and fitting into strong staples in the sides and front board of the cart. In the toy cart the best way is to plane up for this two pieces of ash, about ¼in. square and 3in. to 4in. long, and put them in boiling water till they will bend, then fix and tie them like C, till cold. Bend them, as shown, more at A, B than at the other end. The cross bars may be slightly notched into these, and glued as well as nailed. Use the small wire nails, with round heads, as imitation bolts. Care must be taken to curve the two side pieces exactly alike, and where they come in contact with the edge board already described, a piece must be cut out of it to let them through. In Fig. 22, p. 58, is shown one in place with part of the right side of the cart in perspective; and also a part of the left side in section. The bent bar is seen going down through the top board, and held by the two staples, *a*, *a*, to the side of the cart. Very often in farm carts the top board is omitted, and then it is still more easy to fit up such a frame, as there is nothing in the way to prevent it. These frames will vastly improve the appearance of the toy cart.

The wheels made with a felloe turned and cut into two or three pieces must have a nicely turned nave, and be glued up and finished with a tin tyre painted black. If this is soldered into a ring and made to fit tightly it will not come off, but it may be held by wire nails driven into the felloe over one or two of the spokes, which will thus themselves be further secured.

To make a farm-cart proper, or tip-cart or tumbril, all the above directions will serve, except where the shafts are directed to be glued fast to the bottom boards of the body. In this case they must be quite independent, a pair of shafts braced by two cross-bars instead of one, so as to constitute together a stiff frame. These are then hinged to the main timber of the axle, to which the cart body is also secured, so that the cart body can turn upon the axles, which, with the wheels, form a centre of motion. When down in front, resting on the shafts, the body is held by staples fixed in the shafts which pass through the two timbers under the cart body. I have given an illustration to make this more clear. In Fig. 23, A, B, p. 60, which was in our previous cart part of the shafts, is now an independent timber, to which the axle bar is fixed. It is left at A longer than the cart to form a support when the body is tilted up. The shaft (*c*) is hinged to the axletree, and C, C are the staples fixed in the shaft, and passing through holes in A, B, while, to keep the cart body from tilting when not required to do so, a bar (F) is used, with iron pins at each end to fit into the two staples or eyes.

Following are represented in plan a pair of such shafts to show how they are framed up; and generally an iron band (H) is added for greater security to prevent spreading. All this is easily imitated in our toy cart, and if the main timbers are of oak, and the whole nicely planed and varnished, it will form quite an ornamental toy. But be it remembered varnish will not conceal open joints and defects, and if our cart builder is unable to make very close neat work, he had far better give his productions a couple of coats of paint.

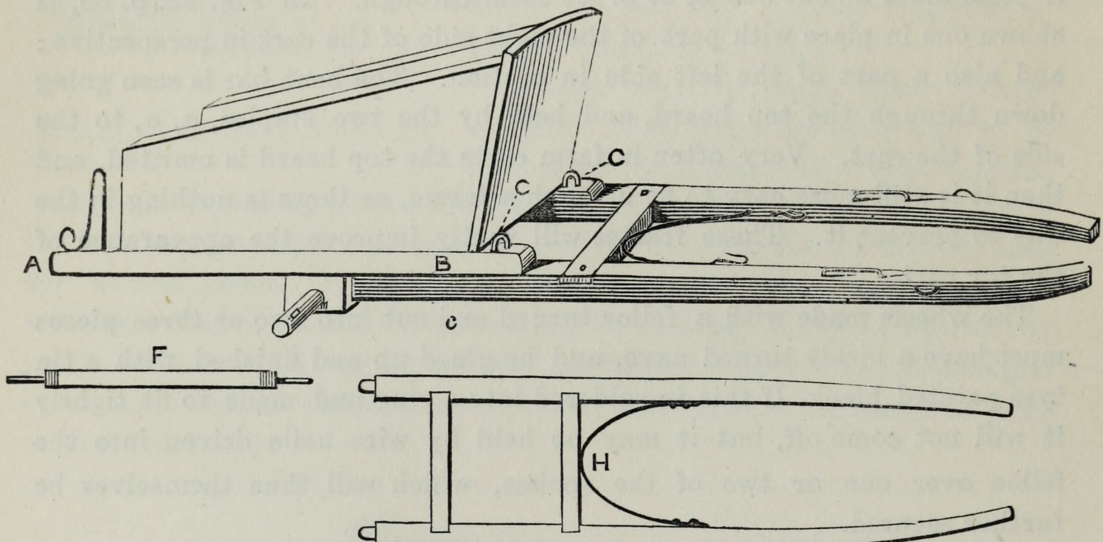


FIG. 23.—TIP-CART OR TUMBRIL.

The practice already obtained in the use of tools will render the construction of a waggon a comparatively easy matter. Still a waggon is not exactly a double-sized cart, for it has certain peculiarities of construction essentially its own. The front wheels are so arranged as to turn on a centre pin, and they have a framework or independent carriage to which their axle is attached, while the hind wheels have no such common horizontal motion. Then, to allow of this motion of the front wheels, the fore part of the body of a waggon needs to be blocked up or cut away, or made higher than the other end, so that the wheels can go partly underneath it without coming in contact with the bottom boards.

As before, I shall commence with the body, which must be made of ¼in. board, neatly planed on both sides. For a toy, the side pieces may well be in one, and not each made of several boards nailed to a frame, though we will in this case add the latter for appearance' sake. If the long side boards are cut like A and B of Fig. 24, p. 61, the front will be thus elevated at once above the hinder part, and although the floor will also rise instead of being level, this will be of no importance at all. Many waggons, too, rise in this way, and have a rather more showy appearance than when they are made with a flat floor. But if thus made we must form the bottom of boards put on the short or cross way, and not lengthwise. We may, indeed, bend a sufficiently thin board to an easy curve, but the best plan will be to work with a single bit of $\frac{1}{4}$in. or $\frac{1}{8}$in. stuff up to where the rise begins, and then make the rest of narrow bits run across, joining them closely and bevelling them to fit neatly against each other. Let the close fitting not be scamped, for it is excellent practice, teaching a good deal of joinery, and household joinery may be made not only an interesting pursuit, but a paying one.

Let the imitation framing and panelling be neatly carried out, as in the cart previously described, but it is only necessary to put upright bars, *a*, *b*, *c*, with a single long one at top and bottom, which should be shaped by a fret saw to the required curve. Where the long edge rails meet those of the front, they must be notched into one another, and fitted as neatly as an Oxford frame. The ends of the upright side bars will be concealed when the top edge boards are put on. This board is held by brackets of iron or wood, as shown at *d*, attached by small nails, or, better still, small screws. These will, perhaps, be easier to make of wood, unless the toy maker can use the soldering iron, but if so, they can be made of a strip of tin bent to the necessary angle, with a third bit of tin or wire soldered on at each end to form the stay or brace. Just a touch of solder will suffice, and will not show when the

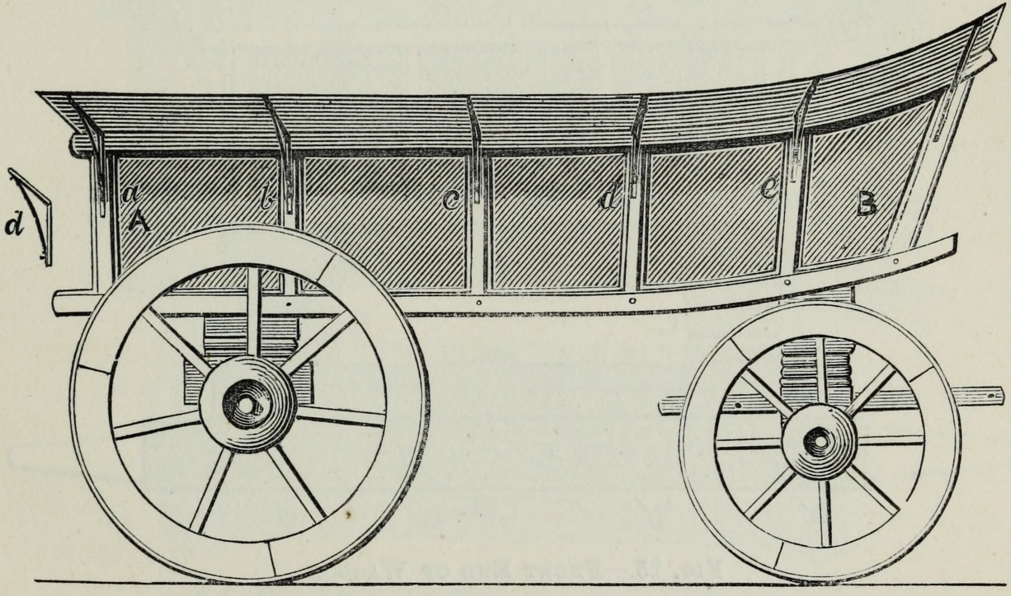


Fig. 24.—Waggon.

whole is painted black or coloured with japan. These little brackets are to be fastened to the upright bars, not to the boards which form the sides.

Fig. 25 is a view of the front end of the waggon, in which all details are given to show how the body is raised so as to allow the wheels to pass under it. A is the body, B a cross beam attached firmly to it; C, C blocks which should be fluted or channelled round their edges to give them a lighter appearance; D a second beam firmly fixed to the under side of the blocks. Through the centre of this is passed the bolt by which the axle, E, and fore carriage (represented complete in Fig. 26) are united to it, so as to turn on it as a centre. In a real waggon a flat ring of iron, dotted in the drawing, is let in flush both in the top of the fore carriage and in the bottom of the beam, E (one in each), so as to form a turntable and prevent undue friction between the surfaces of these pieces of timber. It can be made of stout tin, or omitted in the toy waggon, which will do just as well without it.

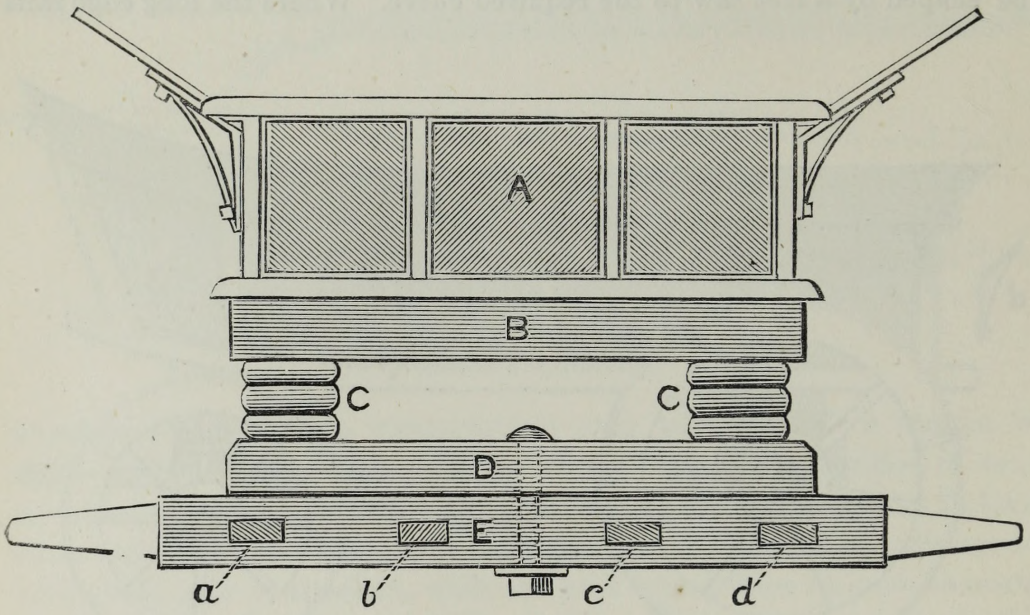


FIG. 25.—FRONT END OF WAGGON.

The square holes *a*, *b*, *c*, *d*, in Fig. 25, are to receive the ends of the bars of the framework of Fig. 26. But it is easier to make round holes than square ones, and even where it may be necessary to use square bars in the construction of any framing, it is a common practice to round the ends to save the time and labour of cutting out square mortices with a chisel and mallet. By means of a lathe these can be quickly and accurately made, but if no lathe is at hand there can be little difficulty in accomplishing the work by hand. For toy work a knife carefully used will serve very well, but the round pin must be kept central, or the frame will be crooked.

I have drawn this waggon front with axles shaped like those of real waggons, and they may be so made, and the wheels kept on by a linch pin. Fig. 26 shows the shafts in position. They lie between the two side pieces A and B of the front frame, and a long bar (C, C) passes through holes in these side pieces and in the frames, forming a hinge. The shafts are, therefore, to be made and framed up very like those of the cart last described. If the waggon is made proportionately broad, a double pair of shafts may be attached, but in that case the front carriage should have another timber similar to the side pieces, fixed in the middle of the front frame, where the two pairs of shafts will meet.

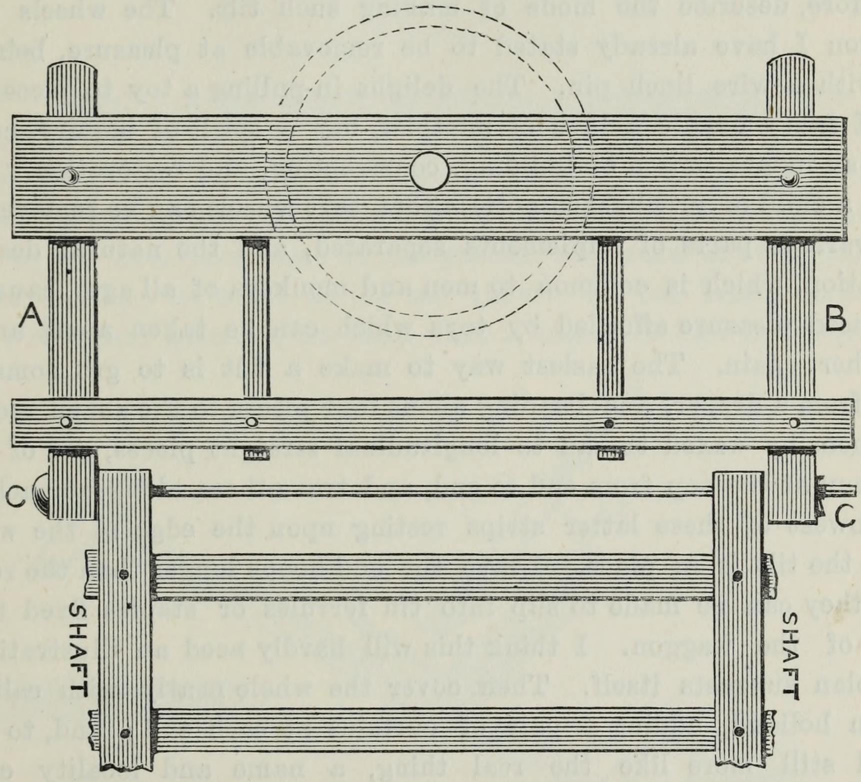


Fig. 26.—Axle and Fore Carriage of Waggon.

This waggon deserves to be nicely painted, not to hide defects, because such are not supposed to exist, but simply that it may be arrayed in all the glories of its compeers. Let the wheels be painted vermilion and the body green—rich dark green—and when this colour is quite dry, take a small sable brush and pick it out with vermilion, laid on in thin even lines round the different parts of the framework, thus panelling it out in green and red. For instance, you may put a line of red along the edge of the side top boards, others a little way from the edge of the various timbers, a line down each shaft, and so forth. Then we must add a name-plate of tin, or paint the name in black and red, or in any bright colour, on one of the side panels, according to law.

A waggon with a curtained tilt, and having wheels that can be taken off, is certain to be duly appreciated by subsequent generations. I will, therefore, describe the mode of making such tilt. The wheels of our waggon I have already stated to be removable at pleasure, being put on with a wire linch pin. The delight in pulling a toy to pieces does not I fancy denote a love of mischief, but a spirit of inquiry, coupled with an innate notion of building, constructing, and restoration. Moreover, a child of intelligence notices that cart wheels can be removed, and the various parts of implements separated, and the natural desire of imitation, which is common to men and monkeys of all ages, causes the enhanced pleasure afforded by toys which can be taken apart and put together again. The easiest way to make a tilt is to get some split cane from a draper, and bending about four pieces to the shape required, tie them by waxed thread to longitudinal straight pieces, one of which will run at the top from end to end, and two others along at each side, the lowest of these latter strips resting upon the edge of the waggon when the tilt is in place. Leave the end hoops longer than the rest, so that they can be made to slip into tin ferrules or staples fixed to the body of the waggon. I think this will hardly need an illustration, as the plan suggests itself. Then cover the whole neatly with calico or brown holland, adding a pair of curtains at each end; and, to make it all still more like the real thing, a name and locality can be painted in black or red letters upon the outside.

CHAPTER IX.

ROLLERS AND WHEELBARROWS.

I will now describe how to make a roller, which, moreover, when of rather larger dimensions than that of the toyshop, is a very useful article to run over seed beds in the garden, where the soil is light, and is almost as easy to make as the toy roller. In the latter, however, which I will first describe, we shall want a frame of deal and a turned cylinder of wood. Taking the handle at 2ft. 6in., or 3ft. at most, according to the size of the child for whom it is intended, it may be planed to a width of $1\frac{1}{2}$in. to 2in., and a thickness of $\frac{3}{8}$in. to $\frac{1}{2}$in. I

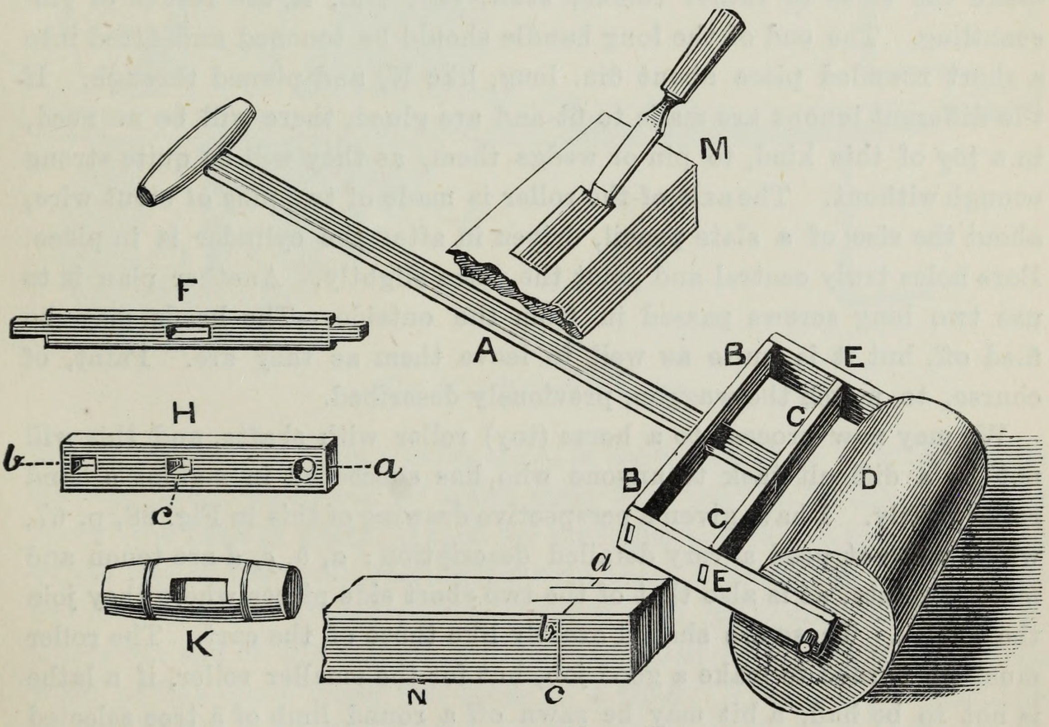


Fig. 27.—Parts of Hand Roller.

have in this case made a drawing to scale, to show the proportion of the different parts. The handle (A, Fig. 27, p. 65) is 3ft. long, the rails (C, C, B, B) are 2ft., the sides (E, E) 1ft. The roller is 9in. diameter, and just long enough to turn easily between the side pieces in which its axles are made to run in two holes, which ought to have little tubes of tin or brass let in. This is called "bushing" the holes, and is done in the case of real rollers, wooden clocks, and other articles of the kind where the axles of wheels have to revolve in holes bored in the wood framing which holds them together. It is often possible to get bits of brass tubing for such purposes as the present, but tin will do almost as well, and it need not be soldered, but only bent round to meet, and then hammered into its place.

F is a plan view of B, B or C, C, which are exactly alike. The central square hole allows the long handle to go through it, fitting well and closely. The ends are to be cut as shown, *i.e.*, with tenons to fit well into mortices in the side pieces, one of which is seen in plan at H. In these pieces *a* is the bushed hole for the roller pin ; *b* and *c* the square holes to receive the tenons of the rails B, B and C, C. It is as well to make the sides of rather thicker stuff, say, ½in., if the rest is of ⅜in. scantling. The end of the long handle should be tenoned and fitted into a short rounded piece about 6in. long, like K, and pinned through. If the different tenons are made to fit and are glued, there will be no need, in a toy of this kind, to pin or wedge them, as they will be quite strong enough without. The axle of the roller is made of two pins of stout wire, about the size of a slate pencil, driven in after the cylinder is in place. Bore holes truly central and point the wires slightly. Another plan is to use two long screws passed in from the outside. The heads may be filed off, but it is quite as well to leave them as they are. Paint, of course, to match the waggon, previously described.

We may now proceed to a horse (toy) roller with shafts, and this will not be a difficult task to anyone who has succeeded in making a hand roller neatly. I have given a perspective drawing of this in Fig. 28, p. 67, which will not need a very detailed description ; *a*, *b*, *c*, *d* are tenon and mortice joints, as is also that of the two short side pieces where they join the shafts. These are shaped exactly like those of the cart. The roller must be turned to make a good job, but for the smaller roller, if a lathe is not to be had, a bit may be sawn off a round limb of a tree selected from the wood pile—a short piece is sometimes very nearly a true cylinder.

Before proceeding further, I think it may be as well to describe in detail the proper way to make a tenon and mortice, as in this consists the main secret of carpentry, whether for toys or large and important work. In Fig. 29, p. 69, A is a carpenter's square, often made entirely of wood by the carpenter himself, but, generally speaking, for the smaller sizes the handle is of hard wood and the blade of steel, and the two are fixed accurately square to each other. B of the same Fig. is a common gauge, and C a mortice gauge. The first consists of a stem of beech or hard wood accurately squared up, and about ½in. wide by 6in. long. Near the end, in one face of this stem, is a point of steel or of iron, very short and sharp, which actually scribes the work when using the tool. Upon this slides a block of hard wood, mortised out to fit the stem and slide upon it stiffly. It is further mortised to hold a wedge; it is marked F and the wedge G, which latter has two heads, to prevent it from falling out and getting lost. The mortice gauge is similarly made except that in the stem is fitted a brass slide, in the end of which is fixed another scribing point, which can be drawn away from the first by the action of a screw (the head of which, shaped for the finger and thumb to hold, is seen at the top of the tool), leaving between them a space the width of the desired mortice. D shows a bit of wood with the square laid across it, where one end of the mortice is to be. A pencil line is drawn along the wood at this place, using the blade as a ruler. The square is then slid down and a second line drawn, thus setting out the two ends of the mortice truly square to the sides of the piece of wood, which I have supposed accurately planed on all sides.

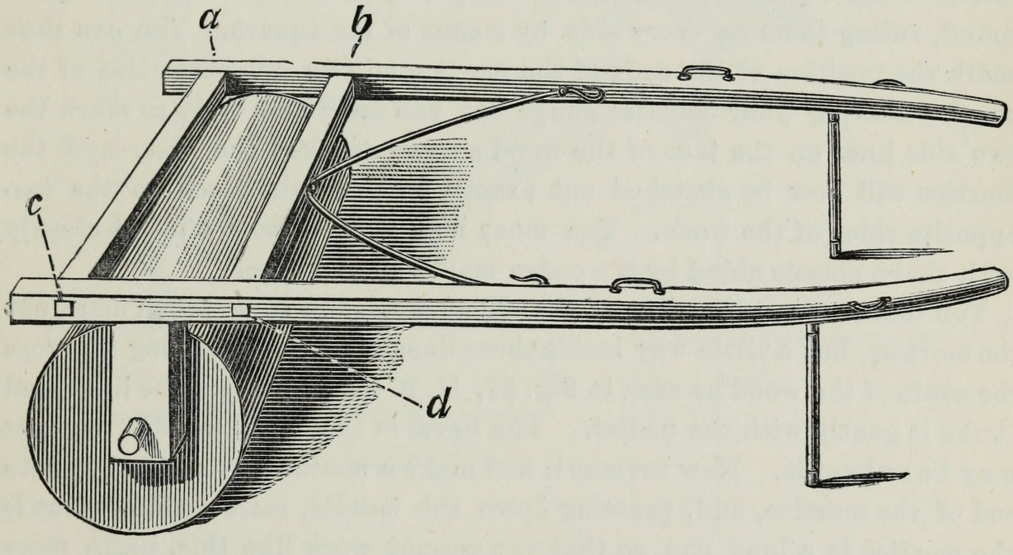


Fig. 28.—Horse Roller.

The sides of the mortice are now to be marked by means of the gauge. This is placed as shown at E, the sliding block having been fixed on its stem at the distance the side of the mortice is to be from the edge of the piece of wood. Holding it by the stem close to the head, or by the head itself in the right hand, and steadying it with the left, the gauge is moved up and down once or twice along the wood, and will scratch or scribe a line upon it as shown on the left side of E. A similar line is then scribed on the opposite side, which completes the marking out of the mortice. If the mortice gauge is used, made, as explained, with two points instead of one, the two lines are scribed at once and at one setting of the tool, which is a much more convenient plan in the majority of cases.

The great difficulty to be overcome is the cutting the mortice accurately, quite perpendicular to the face of the work. A great many are required to be cut through the wood, and when this is the case accuracy may be insured in the following manner: Instead of only drawing the lines by means of the square on one side of the piece, as at D, carry these quite round, ruling them on every side by means of the square. You can thus mark the position of the ends of the mortice on two opposite sides of the wood. Having your mortice gauge set, you have now only to mark the two side lines on the face of the wood as you marked the first, and the mortice will now be sketched out exactly in the right place on the two opposite sides of the work. You must now proceed to cut it out cleanly with sharp chisels aided by a wooden mallet—not hammer.

You must not set the edge of the chisel upon the lines which mark out the mortice, but a little way inside these lines. Begin by setting it across the grain of the wood as seen in Fig. 27, M, p. 65, $\frac{1}{4}$in. within the lines, and strike it gently with the mallet. The bevel of the chisel for this first cut may be outwards. Now reverse it and make a similar cut at the opposite end of the mortice, and, pressing down the handle, raise a chip. But if the mortice is a long one, so that you cannot work like this, begin more in the middle of it, and so extend the hole gradually. When half way through the stuff, or thereabouts, turn it over and begin on the other side, and after a while you will, of course, have cut quite through. You now have to work from each side until you have cut the hole square and true.

Never obliterate the lines marked. Work exactly to them, but leave them on the wood, and let this be a standing rule, or you will never make a good fit. When the mortice is nearly finished you must turn the bevel of the chisel inwards towards the centre of the hole, and at the very last you must re-sharpen the tool, so as to trim the hole very clean. When finished all sides of the mortice ought to be quite smooth, and as true as if planed. Using ordinary care no difficulty should be found in cutting a through hole like this, but when the mortice is not intended to appear on the other side it is very easy to cut it incorrectly by not holding the chisel upright or perpendicularly to the face of the work. When this is the case a tenoned piece fitted to it will not stand correctly at right angles to the first, and, indeed, will not fit at all, unless so cut as not to stand upright. This is often necessary; but, of course, in that case the parts are marked and fitted differently, the bevel being used instead of the square. You can also mark out a mortice with a pair of compasses, measuring the different distances and pricking out the ends of the line and ruling with a pencil and straightedge, but this is not the right method, except in certain special cases, the square and gauge being so much more effective.

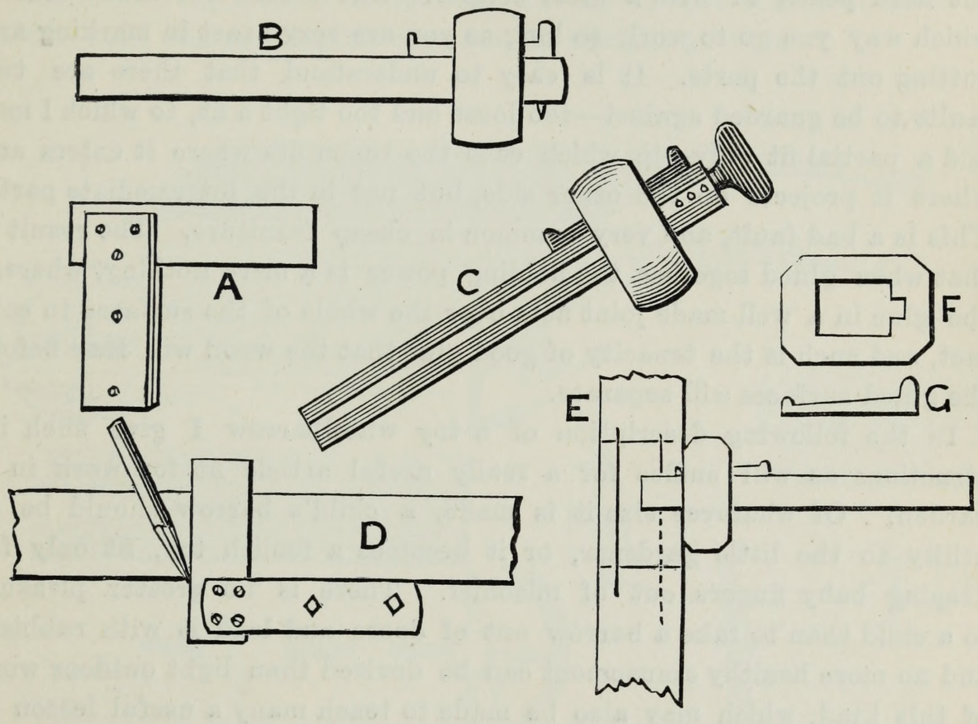


Fig. 29.—Tools used in Mortice Work.

The tenon needs just the same care both in marking and cutting. N of Fig. 27, p. 65, is a bit of wood squared up truly. First mark it all round *a*, *b*, *c*, with the square at the right distance from the end. If the tenon is to go quite through the mortice, let it be long enough to project ½in., which superfluity will be subsequently cut off with a saw and chisel Measure with compasses the size of the tenon required, taking the measurements from the mortice already cut, and having set the gauge accordingly, scribe the longitudinal lines till they meet, or even cross those drawn by the square. Now saw *b*, *c*, and the opposite side, not cutting the line, but sawing so closely and truly that you will not need to trim it subsequently with a chisel. If of deal, straight grained and free from knots at this part, you may now split off the cheek pieces, using a broad chisel and a mallet, and subsequently with a very sharp chisel trim exactly to the lines. But if there is the least doubt about the straight splitting of the wood, saw these cheeks out completely and truly, leaving, I repeat, every line upon the piece. You will then find that the mortice and tenon will fit with great accuracy, though not so tightly as to endanger bursting the mortice, a mishap not unusual, but fatal to any hope of a strong joint.

I have in these instructions reversed the usual order of work, as the tenon is generally cut first, and being then stood on the piece in which the mortice is to be made, a line is drawn round the latter with a finely cut hard pencil or with a steel scriber. But it does not much matter which way you go to work so long as you are very exact in marking and cutting out the parts. It is easy to understand that there are two faults to be guarded against—too loose and too tight a fit, to which I may add a partial fit only—in which case the tenon fits where it enters and where it projects on the other side, but not in the intermediate parts. This is a bad fault, and very common in cheap furniture. The result is that when glued together the holding power is a mere nothing, whereas the glue in a well-made joint acts over the whole of the surfaces in contact, and such is the tenacity of good glue that the wood will tear before the glued surfaces will separate.

In the following description of a toy wheelbarrow I give such instructions as will suffice for a really useful article fit for work in a garden. Of whatever size it is made, a child's barrow should be of utility to the little gardener, or it becomes a foolish toy, fit only for keeping baby fingers out of mischief. There is no greater pleasure to a child than to take a barrow out of doors and load it with rubbish, and no more healthy amusement can be devised than light outdoor work of this kind, which may also be made to teach many a useful lesson of tidiness and industry.

The ordinary child's barrow (A, Fig. 30, p. 71) is constructed in the simplest manner that can be devised, and is not by any means a bad one. It might, with one or two modifications, answer on a larger scale, and it certainly has the advantage over those in daily use that it is much less prone to tip over sideways, because the centre of gravity is below the level of the hands. But this is an advantage with a drawback. It is better for wheeling, but renders it difficult to discharge the load at the end of the journey, and hence it is, I suppose, that this design has not gained favour. But for children's use it is perfect, because their difficulty always is to prevent an upset, and if they try to wheel a barrow of ordinary shape fairly loaded they generally capsize the whole before arriving at their destination.

Each side is made of a single board sawn out to the form shown. The front, cut like C, and the back of similar form, are then nailed inside these. These front and back boards ought to be thicker than the sides, to make a strong job, because, if thin, you have to use nails too slight to hold all securely. The bottom, which also forms the bearing of the wheel, is cut like B, the wheel running in the slot. By an oversight I have made this a barrow that will tip easily like that used by gardeners; for a child's safe barrow the sides are continued like short shafts to take the wheel, the axle thus lying above the centre of gravity of the load. D shows one leg sloped off towards the top to suit the outward slope of the side, and so bring the legs into an upright position.

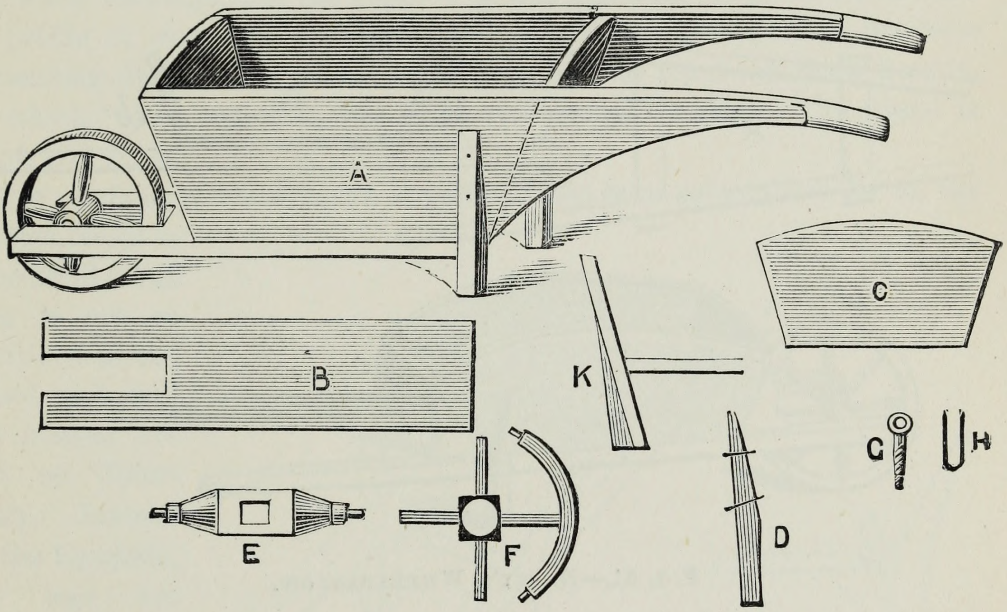


FIG. 30.—ORDINARY WHEELBARROW.

The arrangement of these essential parts of a toy barrow is always faulty, and very soon the legs are seen to have taken up a walking position instead of remaining perpendicular. To prevent this, there should always be a stay of light iron rod (if the barrow is intended for use) attached at one end to the bottom of the leg and at the other to the under side of the bottom of the barrow.

In a mere toy when it is easy to find stuff wide enough, the side boards may even be shaped like the dotted line, and thus form the legs; but, if so, these boards must not splay or slope outward much, as they will throw the parts forming the legs too far out of the perpendicular. In this case a bit of stuff can be sloped like K and nailed on outside (K, the part shaded, being an independent leg similar to D, but nailed all the way down, and thus forming a much stronger support than when cut and attached with only a nail or two in its upper end). The parts of the side boards which form the handles are rounded off with a spokeshave, so as not to hurt the hands.

A barrow wheel, if made of wood, is always formed in a peculiar way, unlike any other wheel. The nave, square in the middle, slopes off at each end, and has iron ferrules driven on to prevent splitting, as the pivots are driven in and have to bear the weight of the load and stand the ceaseless strain and jar of wheeling it. Through the middle of the squared part a mortice is cut in one direction to receive the piece F, Fig. 30, p. 71, which forms two spokes, and is shaped as shown, fitting the mortice in the middle, and being rounded at the ends to go into holes bored in the rim or felloe. This being put in place, a hole is now pierced through the axle in the other direction, passing, of course, through the centre of the piece just described. This is a round hole, and a portion of rounded ash, or oak, or elm, forming the other two spokes of the wheel, is now driven in tightly, fixing the flat portion securely and completing this part of the wheel. The rim, made of two, or at most of three, separate pieces, as already described, is now fitted on and worked up to a correct form, and an iron tyre completes it. Such is the mode of construction without independent framing, which generally finds favour with toy-makers. Nothing can be better for a child's barrow.

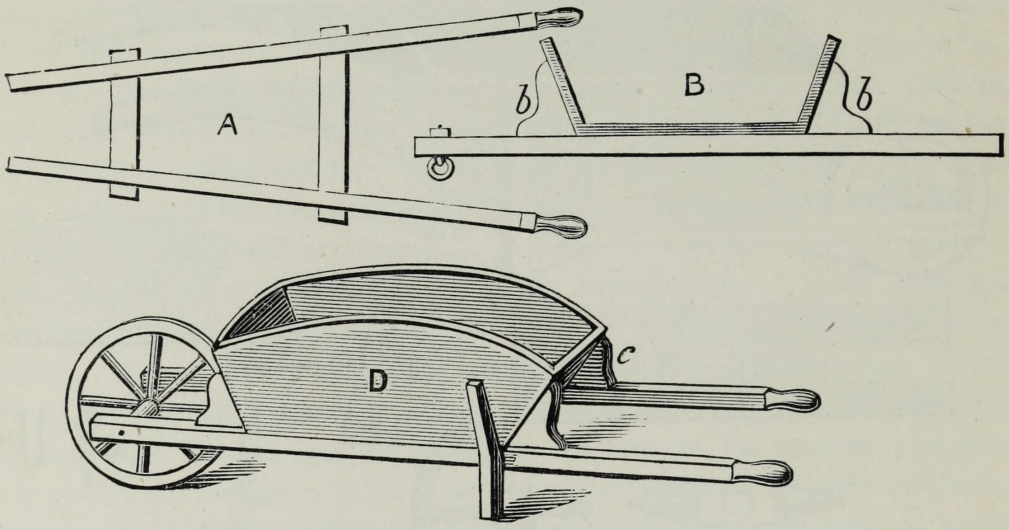


FIG. 31.—NAVVY'S WHEELBARROW.

We will now, however, progress a step further, and make this article with a frame. There are two patterns general even in this case, viz., that of the navvy barrow used in the construction of railroads, and intended to carry a comparatively small load and tip easily, and the deep barrow of the gardener, which is often made still deeper by additional top boards, that can be added and removed at pleasure, the object being to enable large loads of dead leaves to be carried in the autumn.

The navvy barrow is a simple affair, and is designed to be, to a certain extent, portable, *i.e.*, the main parts can be so made as to pack flat for shipboard or train, and on arrival at their destination these can be put together in a very short time without much knowledge of carpentry. In Fig. 31, p. 72, A is the bottom frame of ash, forming at once the shafts, the wheel bearings, and the support of the bottom. B gives a side view or profile of one side of this frame, and shows two wooden brackets separately drawn at *c*, nailed on to support the front and back boards, to which, when attached, the sides are securely nailed. The wheel is always of iron.

The gardener's wheelbarrow is made on the same principle so far as the bottom frame is concerned; but this is not so narrowed at the wheel end, and the boards are put on differently. Instead of the brackets, the legs are notched out and fitted on, as seen in section (Fig. 32) A, and in perspective in 32, B, so that their upper part forms a support to the side boards. Two pieces (C, C) mortised into the shafts at the wheel end support the back, and the latter at this point support in turn the further ends of the sides. An iron rod, generally speaking, goes from one leg to the other, as shown at the dotted line, and this, which has a large head at one end, is fixed with a nut at the other, adding considerably to the strength of this part. A band of hoop iron is also frequently put across the top edge of the back

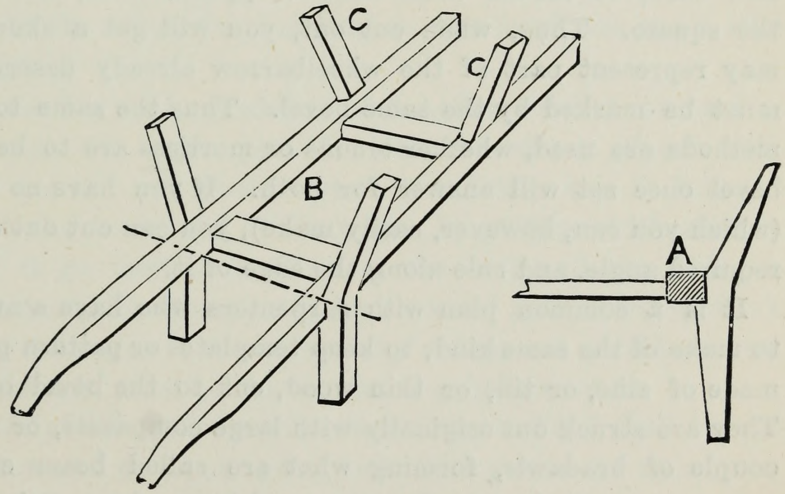


Fig. 32.—Gardener's Wheelbarrow.

board and over the sides to which it is nailed, which prevents so much strain falling upon the nails which hold these together. A heavy load is thus prevented from bursting out the sides of the barrow.

Even if this garden implement is only intended as a fairly useful toy, it should be made, if possible, of ash, and all parts well and strongly joined together. It is not a difficult article to construct, and will afford good practice. Care must be taken to cut the top part of the legs to exactly the same angle, and to place C, C at a similar angle, or the barrow will be crooked, and only fit to be stuck upon a pole and labelled "failure," as a warning to the amateur carpenter to take more care.

There now arises the question, How are we to insure the correctness of the aforesaid angles of our wheelbarrow? for it is a frequent occurrence in carpentry that pieces have to be united together at other than right angles. The tool used in such cases is the bevel illustrated in Chapter I., Fig. 1, p. 6—a sort of square with movable blade. It is used very much in the same way as a square, but the blade is first set to the required angle. Suppose you wish to cut a sloping mortice. The side lines are to be ruled on each side of the piece by means of the bevel, while the others, and those to match them on the opposite side, are to be drawn by the square. Thus, when cut out, you will get a skew mortice, which may represent part of the wheelbarrow already described. The tenon must be marked by the same bevel. Thus the same tools and the same methods are used, whether tenons or mortices are to be drawn, and the bevel once set will answer for both. If you have no carpenter's bevel (which you can, however, easily make), you can cut out a bit of tin to the required angle, and rule along the edge of it.

It is a common plan with carpenters who have a number of articles to make of the same kind, to keep templates or pattern plates of this sort, made of zinc, or tin, or thin wood, cut to the bevel or curve required. They are struck out originally with large compasses, or with a lath and a couple of bradawls, forming what are called beam compasses, if the segments are to be wheel patterns of large size. Others which are not parts of circles are drawn out in pencil by the eye, and, after being cut out, are neatly finished to accuracy. But once carefully made they should also be carefully kept, and not allowed to lie about on the floor till trodden upon and broken or lost.

CHAPTER X.

WINDMILLS AND HANDMILLS.

There is, perhaps, no toy that allows of the exercise of ingenuity as much as the windmill. We meet with it in various forms in the toy shops, and there are many others which it may take until it becomes an absolutely correct model of the well-known machine. The simpest toy windmill is that consisting of four light arms with coloured paper attached to the ends, and a pin or small nail through the centre, by which these small sails are attached to the end of a light rod, but so as to turn freely upon it. Faced to the wind, the rod held in the hand, the small sails spin merrily enough.

Then we have the toy mill, consisting of a hollow wooden tower 4in. to 6in. high, through the upper part of which the axle is placed, with sails of wood at one end. A string wound round this axle is brought down and out at the lower end of the tower, by pulling which sharply and then letting it go motion is given to the sail, and the string is rewound in the contrary direction, ready for a second pull. I do not think this worth further notice, as it is a mere baby's toy, and would at best be only worth making in order to practise turning hollow work.

The first toy windmill I shall describe, therefore, in detail shall be one which I myself possessed as a youngster, and which gave me, I remember, great pleasure, although I had to turn the sails myself by means of a small handle. But it was made to take apart, and it had a click-clack attachment, to say nothing of a flight of steps, or step ladder, on which stood in all his glory the miller himself. Then there were sacks that could be hoisted by a chain through a veritable trap door, and it was a toy of which, curiously enough, I have never seen the counterpart. I shall, however, make one forthwith for some young hopefuls, since the necessity for writing this book has brought the original vividly to my recollection.

First of all there was the stand, consisting of a square board about 2in. each way, with four knobs at the corners to make it stand more firmly. This will be better if made 3in. square of ½in. deal, as it has to support the whole structure, and it will be still better weighted underneath by attaching to it a bit of sheet lead. It will not then require to be steadied by the hand while working the sails. In the drawing opposite (Fig. 33), which is partly sectional to show the inside of the mill, this stand is marked A. In the centre of this board is glued a round turned boss (B) to add to its thickness, and thereby give greater steadiness to the pillar which comes next to it. This may be 1¼in. in diameter, and ¼in. or more in thickness. In the centre of it a hole must be made about the size of a cedar pencil, which must also penetrate through the square board. It will be best made by a shell bit or nose bit used in the brace—a gimlet may split the wood, and will not make so smooth and round a hole. We now arrive at (E) a turned pillar, 1½in. to 2in. long and about 1in. in diameter, which is to be turned with two tenons or pins, one to fit the hole just described, the other, a similar one, to enter in the bottom board and boss of the mill itself. This pillar should be made of beech or ash, not of deal; but, if the latter is used, it will be as well to bore holes and glue in these pins made of some harder wood. C is a boss similar to B glued to the centre of D, and serving a similar purpose. D may be 3in. square, *i.e.*, the same size as the lower board, and ⅜in. thick. Near the corners holes are to be bored, but not so large as the others, say, the size of a penholder. It is as well to put a boss also under each of these corner holes, as they prevent the wood from splitting if put with the grain across that of the board to which they are attached.

All the parts described should be made as neatly as possible, so as to fit together without the least shakiness. For a thoroughly good job the bottom board might be of ¼in. stuff only, with strips ⅜in. broad glued on, so as to give it the form of a framed panel, which will prevent it from warping. If this is not done let the stuff be very dry, and use by preference a harder wood than deal. Let it be quite square with nice clean sharply cut edges. Thus far we have built up the stand and floor. This may be glued up, of course, if preferred, but one chief pleasure of this kind of toy is derived from taking it apart and building it again *ad libitum;* and I should not glue any part of it until perhaps by frequent use it may have become shaky. It might then be glued together and remain as an ordinary toy. We now have to plane up the angle pieces (H), which also fit by pegs into the bottom where the holes were made for that purpose. Here again,

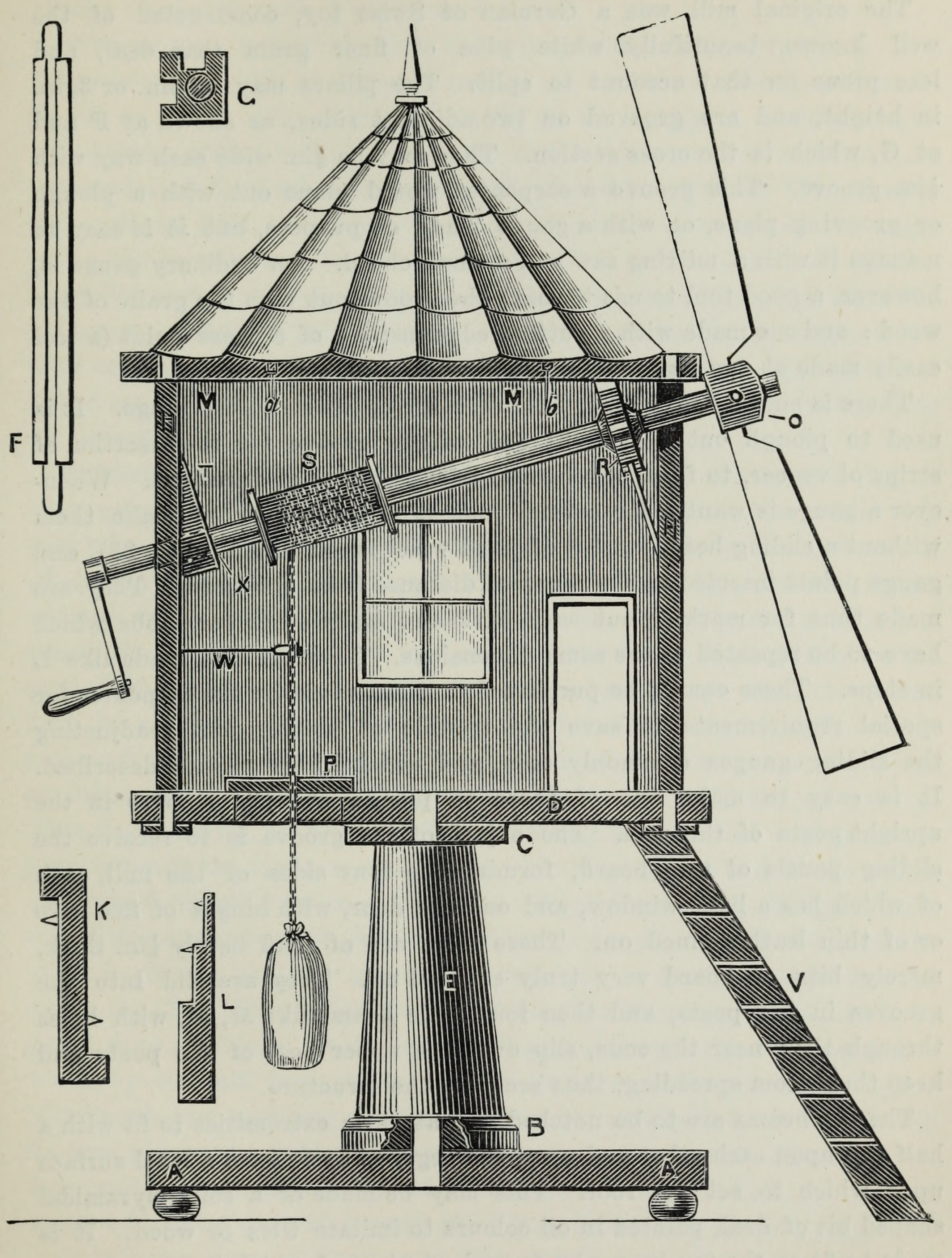


Fig. 33.—Simple Mill with Click-Clack Attachment.

as in the rest of the main framework, deal is not so good a material as beech or ash, but it will do fairly well.

The original mill was a German or Swiss toy, constructed of the well known beautifully white pine of finer grain than deal, and less prone on that account to split. The pillars may be 3in. or 3½in. in height, and are grooved on two adjacent sides, as shown at F and at G, which is the cross section. They may be ⅜in. wide each way with ⅛in. groove. This groove a carpenter would plane out with a plough or grooving plane, or with a gauge made on purpose, but it is easy to manage it with a mitring saw and a small chisel. An ordinary gauge is, however, a good tool to use to mark the groove out with the grain of the wood; and one made with a cutting edge instead of a mere point (a tool easily made at any time) will do such work most efficiently.

There is such a tool called, I think, a string or stringing gauge. It is used to plough out a straight and narrow groove for the insertion of strips of veneer, to form ornamental lines in pieces of furniture. Whenever a gauge is wanted for special jobs it is quite easy to make them without a sliding head. A bit of hard wood is cut like K (Fig. 33), and gauge points inserted at the required distance from the head. They are made thus for marking out sash work and many other such jobs which have to be repeated to the same dimensions. They are also made like L in steps. These cannot be purchased, but are made by the carpenter for special requirements to save the trouble of setting and readjusting the sliding gauges commonly seen, and which I have already described. It is easy to make one of these to plough out the grooves in the upright posts of the mill. The object of the groove is to receive the sliding panels of thin board, forming the four sides of the mill, each of which has a little window, and one the door, with hinges of fine wire or of thin leather glued on. These sides are of stuff barely ⅛in. thick, merely bits of board very truly squared up. They are slid into the grooves in the posts, and then four little beams like M, M, with holes through them near the ends, slip over the upper pegs of the posts and keep them from spreading, thus securing the structure.

The top beams are to be notched out at their extremities to fit with a half lap upon each other and upon the pegs, so as to form a level surface upon which to set the roof. This may be made of a solid pyramidal shaped bit of deal, painted in oil colours to imitate tiles or wood. It is made to fit on the top beams by four short pins, of which two are seen in *a*, *b*. On the summit is a turned ornament or a weathercock. In one part of the floor a trap door (P) is made and hinged with leather. Through this the chain falls for lifting sacks. The windows should have glass put in, which may be secured inside where not seen by strips of calico glued over its edges and attached to the boards. Very thin glass should be used to make a neat job of it.

We now have to form the sails and arrange the axle to carry them. The latter is turned with an enlarged part at O, or this is turned and made to slip on stiffly. The axle is also made to fit tightly in a wooden cog-wheel and a cotton reel (S). Its lower end is made smaller, so as to have a shoulder at X, which rests against the three-cornered bit (T), glued to the wall on that side, and which is necessary on account of the angle which the axle itself makes with the side of the mill. The wheel (R) has a wooden spring resting on the cogs to cause the clacking noise when the sails turn. The spring is fastened securely at one end to the inside of the wall nearest to the wheel. The sails or vanes are merely thin pieces of board cut as shown, and rounded at the end to fit into holes in the boss of the axle.

Not being intended to turn by the wind, these may stand quite flat, as they generally do, or they may be turned in the holes to set at any desired angle, in which case the wind will of course drive them, if set out of doors; but this is not meant as an out-of-door toy, and had better remain as an indoor one for the table. In order to get the axle into place, the side (H), through which it passes, has a U shaped piece cut out of its upper side, the width of which just allows the axle to pass into it, and rest on the bottom. The handle at the opposite end is removed, and this end placed in its block until it rests against the block at the shoulder. The sail end then drops down into its U shaped bearing. This is, of course, all arranged before putting on the roof. W is a wire loop to guide the chain, so that it may not slip off the end of the cotton reel, which should be turned with large flanges. Indeed, though I have called it a cotton reel, it should be made on purpose. I have shown the steps in section, the view giving the inside of the further board forming one side. The other is like it with grooves for the steps, which are to be glued in or fixed with small brads. The upper end may rest against a block by the mill door, or be made to hook on with two wire staples, This toy is one requiring a little care to make neatly and so that it will be firm when put together, but will not present any real difficulty. It is a capital toy to construct, and should have a box to hold it. It will make a birthday present for any child from 3 to 5 or 6 years of age.

It is by no means difficult to modify certain toys so as to render them more or less serviceable, and we can do so with the handmill, adding thereby to the satisfaction of the maker and user. Perhaps the best use to turn it to will be sugar grating or grinding, and the sugar can be sifted and made to run out of a spout into little sacks, thus imitating the work of a real mill. But it is to be noted that when a toy has to do real work it must be strongly made, and we must now have a main spindle of beech or ash with a handle of similar material, which handle is to be long enough to give good leverage. The base or stand should also now be weighted with lead or made to clamp to the edge of a table by the small American clamps given previously. What we require is first of all some form of grater like that used for nutmeg attached to the axle of the sails. Properly speaking, to imitate more precisely a mill, we should place it horizontally and work it by a pinion or "trundle" from a large wheel on the spindle, but this needs more power in order to turn it and overcome the resistance of grinding, and it also needs a little knowledge of wheels and pinions, which I do not wish to give till later on.

We have a choice of form in respect of the grating contrivance, and must consider what will be easiest to make rather than what is absolutely the best. If a nutmeg grater is examined it will be seen to consist of a bit of tin, which has been perforated by a punch from one side only, the rough edge thereby produced on the opposite side fulfilling the office of a grinding surface. The shape given to the grater depends on convenience, some being cylindrical, to fit into a neat case, others flat or rounded, while others, like the American carrot grater, are of much larger size, working by small cog wheels, and are of cylindrical form, with an axle through the axis of the cylinder. Of these forms I think the cylindrical will best answer our purpose, because it will not be difficult to find the material partly shaped to hand. We can get, I daresay, a round tin box about an inch deep and a couple of inches across. Taking off the cover, it will be easy with a punch (any bit of iron or steel ground to a rather blunt point and about 4in. long) and light hammer, working from the inside of the box, to render the outside a very capital grater. A hole must now be made in the middle of the cover and also of the bottom, large enough to admit the axle stiffly.

This axle is to be turned with a shoulder like Fig. 34, A, for the grater to rest against; and a spring driven in through the tin into the axle, will hold it securely enough to prevent it from turning; or if you like to make a still better job, glue on first a round disc, like that dotted, and then, before putting on the cover of the box, tack it through the bottom to this disc; or, thirdly, turn it round, not using the cover at all, but inserting the disc just inside it, and so making the latter form the cover; give it a small tack or two at the edge of the disc. The black line, B, represents a hole to allow any sugar that may accumulate inside the box to be shaken out; most of it, however, will fall out at the punched holes. It will be better, I think, if the mill is to be used in this way, to let the axle run horizontally through the mill instead of lying at an angle, which latter plan is of no real importance in a toy, although in a real mill it is found necessary, in order to gain as much wind pressure as possible, and also to assist in reducing the strain which would be caused by so great a weight as the sails if their axle was horizontal.

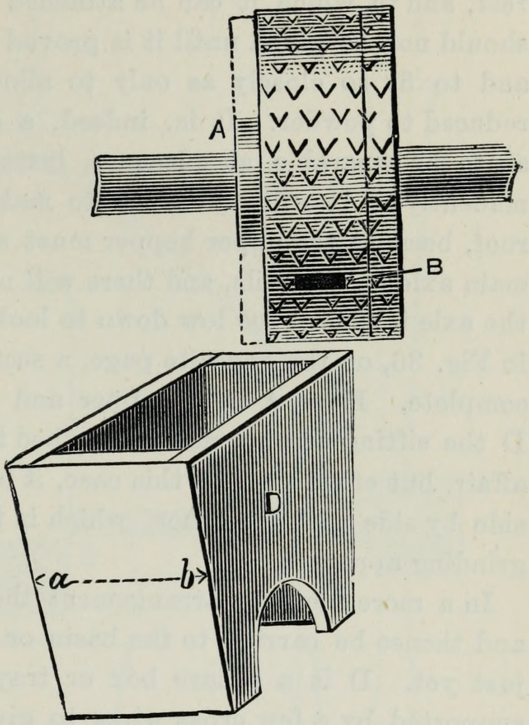


Fig. 34.—Hopper and Grater.

We now want a hopper in which to place the sugar to lead it to the grater, and also a receptacle below to catch it when pulverised, and we can add a sieve to render the ground portion as fine as possible. D represents the hopper. From *a* to *b* is to be the width of the tin grater. In the other direction, it must be as wide as will allow it to fit nicely over the grater, the hollowed part below resting almost upon the axle. A sectional view (Fig. 35) will make this more clear, as it shows us the hopper full of sugar, with the grater inside, half of the latter being encompassed by the hopper. This can be made of wood $\frac{1}{4}$in. thick, as we have not as yet given instructions for using the soldering iron. A similar receptacle or a tin funnel below, will catch the powdered sugar and conduct it into a basin or a small toy sack. The spout can come out below through the floor, or it may lead into a little shoot opening out at the side, details of which I think may fairly be left to the taste and ingenuity of the maker.

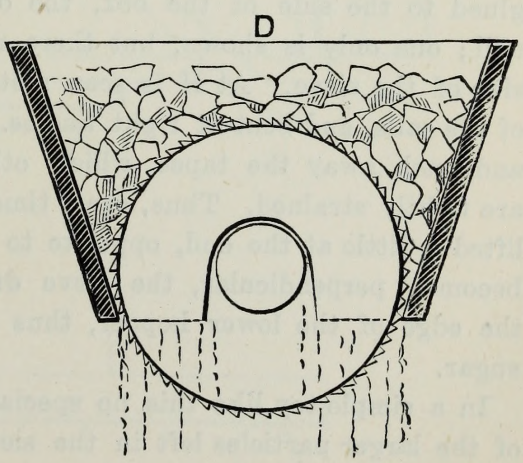


Fig. 35.—Sectional View of Hopper.

The hopper (as also the bottom receptacle) can easily be fixed in its place inside by glueing on blocks inside the walls, between which it can rest, and to which it can be attached by small screws or wire pins. It should not be glued until it is proved to be exactly in the right position, and to fit so closely as only to allow the sugar to escape after being reduced to powder. It is, indeed, a good plan to arrange all parts so as to be separable at pleasure, instead of glueing them together permanently. It will be better to make this sugar mill with a hollow roof, because the upper hopper must stand chiefly above the level of the main axle of the sails, and there will not otherwise be room for it unless the axle is placed too low down to look well. To render all clear I give in Fig. 36, on the opposite page, a section of the mill to show the inside complete. Here A is the upper and C the lower hopper, B the grater, D the sifting arrangement, described further on. This is a very simple affair, but effective. In this case, it is intended to have a special hopper side by side with the other, which is to be filled from the produce of the grinding apparatus.

In a more complete arrangement the sugar should fall into the sieve, and thence be carried to the basin or sack, but we must not attempt it just yet. D is a square box or tray with a bottom of coarse muslin, supported by a few cross wires to give it strength, or it may be of tin pierced with holes, or perforated zinc, or finely-woven wire. This is hinged at G to the side of the mill by two hinges of leather glued on, of which one is seen at G, and the bottom has two little blocks (K) glued on, by which it rests on the edge of the hopper (F). E is a bit of tape, one end glued to the side of the box, the other to a bar at the top of the mill; one only is shown, but there may be two, one attached to each side of the sieve. At H is seen a stout wire, passed through the axle of the sails, and bent at right angles. It must be long enough to strike and push away the tapes, which otherwise hang perpendicularly and are tightly strained. Thus, every time the wire touches a tape the box is lifted a little at the end, opposite to the hinges, and then, as the wire becomes perpendicular, the sieve drops with its blocks below upon the edge of the lower hopper, thus receiving a shake, which sifts the sugar.

In a simple toy like this no special provision is made for the removal of the larger particles left in the sieve. Perhaps the easiest way will be to take off the roof and turn the mill upside down now and then; or the mill door can be made at this place so as to admit a teaspoon, or to allow the sieve, which can be merely hooked on to little wire staples, to be removed entirely. Instead of a second hopper, moreover, the charge to fill the sieve can be introduced at the door and passed at once into the sieve, saving a little extra work in the construction. If

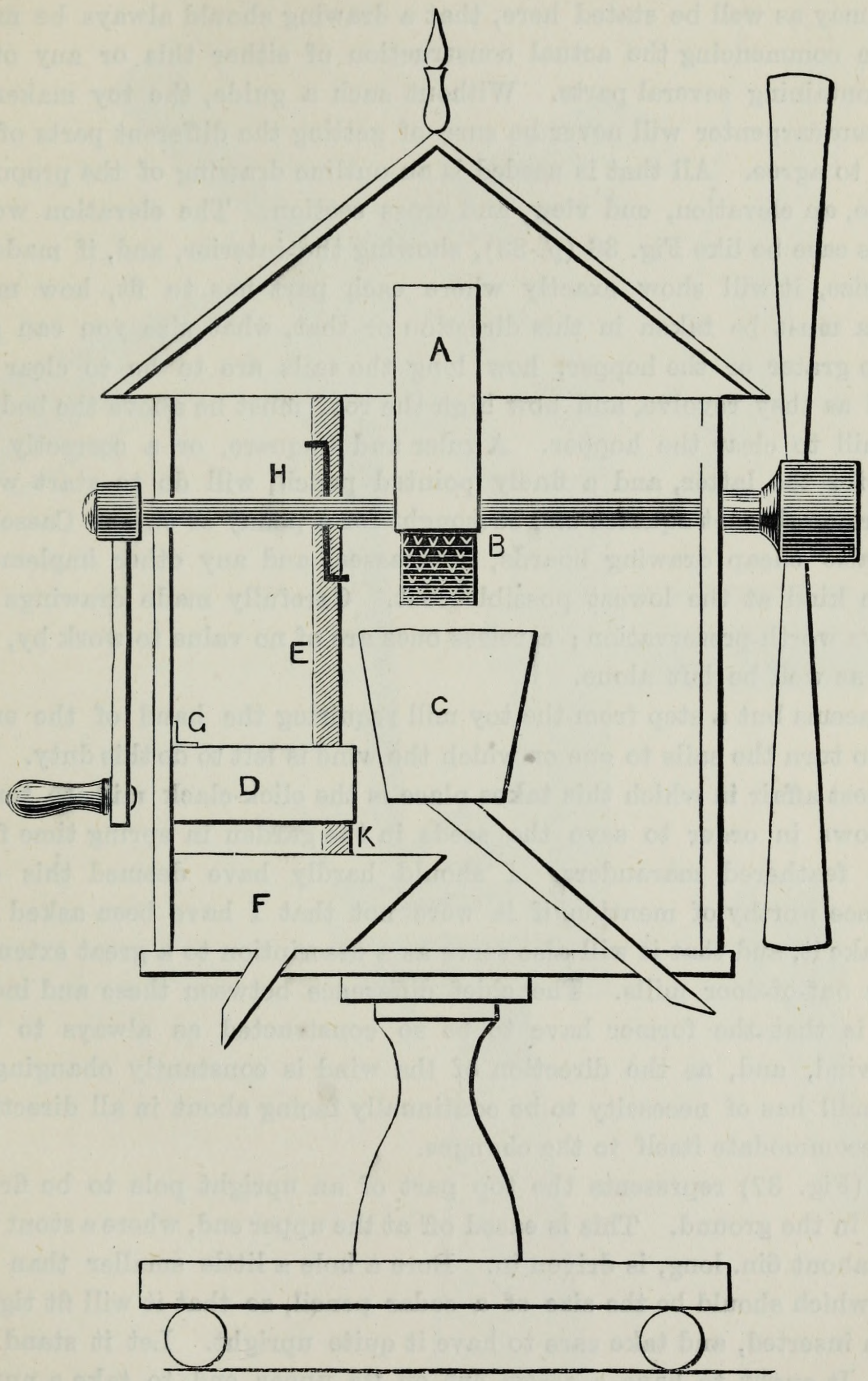


FIG. 36.—SECTIONAL VIEW OF INTERIOR OF MILL.

the handle be 2in. or a little more in the cranked part, plenty of power will be obtained for sugar grating, the work will be done effectually and rapidly, especially if the lumps be first broken to the size of a hazelnut. Sifting, if the sieve is a fine mesh, will, of course, take somewhat longer.

It may as well be stated here, that a drawing should always be made before commencing the actual construction of either this or any other toy containing several parts. Without such a guide, the toy maker or amateur carpenter will never be sure of getting the different parts of his work to agree. All that is needed is an outline drawing of the proposed article, an elevation, end view, and cross section. The elevation would in this case be like Fig. 36 (p. 83), showing the interior, and, if made of full size, it will show exactly where each part has to fit, how many inches must be taken in this direction or that, what size you can give to the grater or the hopper, how long the sails are to be to clear the stand as they revolve, and how high the roof must be above the body of the mill to clear the hopper. A ruler and a square, or a correctly cut card for the latter, and a finely pointed pencil, will do to start with, but triangular set squares can be bought for a penny or two at Cassell's, and also cheap drawing boards, compasses, and any other implements of the kind at the lowest possible cost. Carefully made drawings are always worth preservation; careless ones are of no value to work by, and may as well be left alone.

It seems but a step from the toy mill requiring the hand of the small boy to turn the sails to one on which the wind is left to do this duty. The smallest affair in which this takes place is the click-clack mill, to terrify sparrows in order to save the seeds in the garden in spring time from these feathered marauders. I should hardly have deemed this contrivance worthy of mention if it were not that I have been asked how to make it, and that it will also serve as a description to a great extent of other out-of-door mills. The chief difference between these and indoor toys is that the former have to be so constructed as always to face the wind, and, as the direction of the wind is constantly changing, a windmill has of necessity to be continually facing about in all directions to accommodate itself to the changes.

A (Fig. 37) represents the top part of an upright pole to be firmly fixed in the ground. This is eased off at the upper end, where a stout iron rod, about 6in. long, is driven in. Bore a hole a little smaller than this rod, which should be the size of a cedar pencil, so that it will fit tightly when inserted, and take care to have it quite upright. Let it stand out 3in. It ought to have a screw cut on its upper end, to take a nut—a blacksmith's job—but we can, I dare say, manage to do as well without it. The actual mill consists of a frame of wood, which I think the drawing will explain. G is to be 1½in. thick and 6in. long, if of deal, or

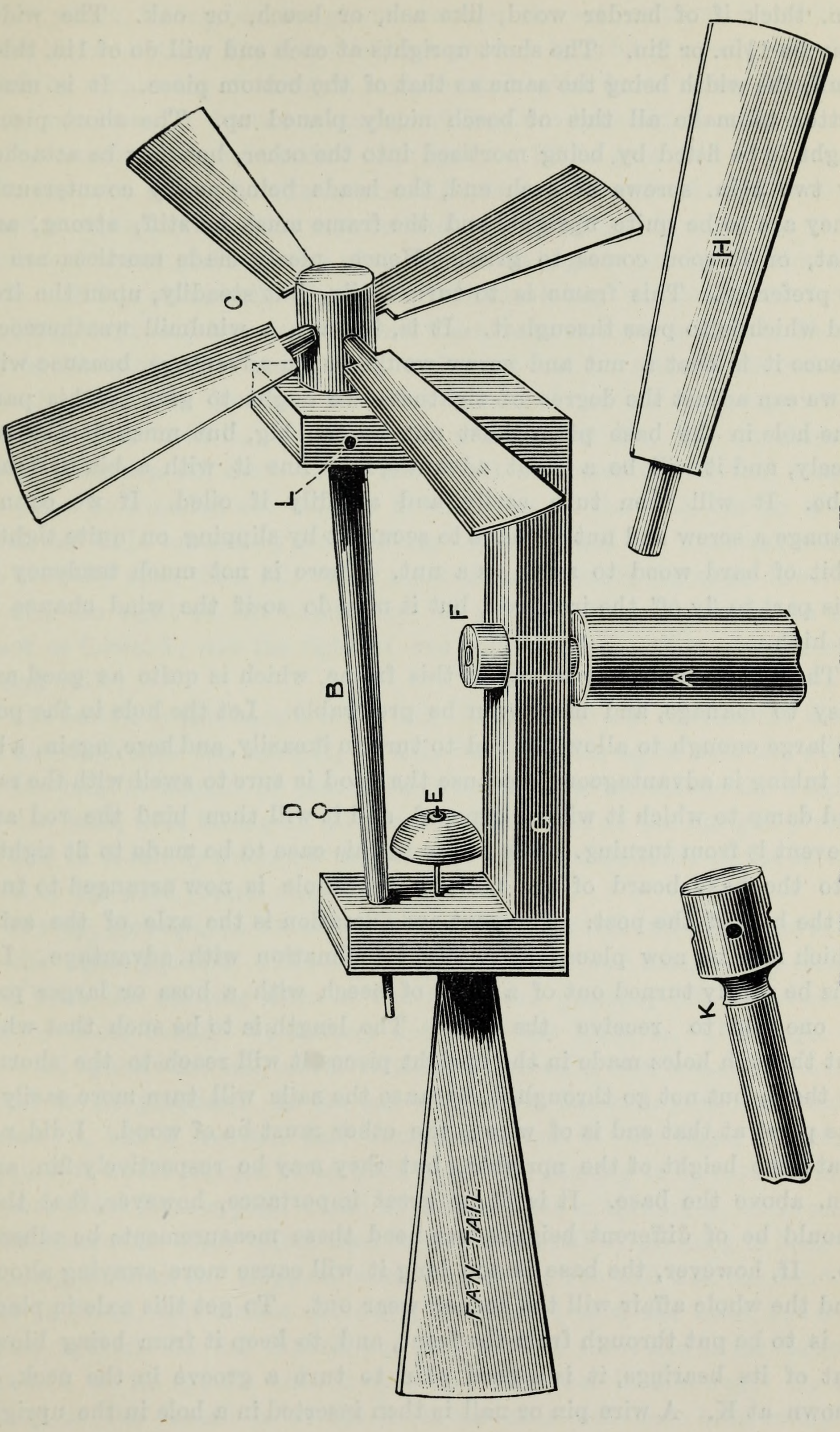


FIG. 37.—DETAIL OF TOY OR CLICK-CLACK WINDMILL.

1in. thick if of harder wood, like ash, or beech, or oak. The width may be 1½in. or 2in. The short uprights at each end will do of 1in. thick stuff, the width being the same as that of the bottom piece. It is much better to make all this of beech nicely planed up. The short pieces ought to be fitted by being mortised into the other, but may be attached by two 1½in. screws at each end, the heads being neatly countersunk. They are to be quite upright, and the frame must be stiff, strong, and neat, or it soon comes to grief. Hence, nicely made mortices are to be preferred. This frame is to turn easily, but steadily, upon the iron rod which is to pass through it. It is, in fact, a windmill weathercock. Hence it is that a nut and screw would be an advantage, because with it we can adjust the degree of tightness we ought to give to this part. The hole in the base piece must not be too big, but must fit the rod nicely, and it will be a great advantage to line it with a bit of brass tube. It will then turn easily and steadily if oiled. If we cannot manage a screw and nut we have to secure it by slipping on quite tightly a bit of hard wood to serve as a nut. There is not much tendency in this part to fly off the iron rod, but it may do so if the wind chance to be high.

There is another way to mount this frame, which is quite as good and easy to manage, and may even be preferable. Let the hole in the post be large enough to allow the rod to turn in it easily, and here, again, a bit of tubing is advantageous, because the wood is sure to swell with the rain and damp to which it will be exposed, and it will then bind the rod and prevent it from turning. The rod is in this case to be made to fit tightly into the base board of the mill, as the whole is now arranged to turn in the hole of the post. The next consideration is the axle of the sails, which may be now placed at a slight inclination with advantage. Let this be neatly turned out of a piece of beech with a boss or larger part at one end to receive the sails. The length is to be such that when put through holes made in the upright pieces it will reach to the shorter of these, but not go through it, because the sails will turn more easily if the pivot at that end is of wire; the other must be of wood. I did not state the height of the uprights, but they may be respectively 2in. and 1in. above the base. It is of no great importance, however, that they should be of different heights, nor need these measurements be adhered to. If, however, the base is too long it will cause more swaying about, and the whole affair will the sooner wear out. To get this axle in place, it is to be put through from the front, and, to keep it from being blown out of its bearings, it is a good plan to turn a groove in the neck, as shown at K. A wire pin or nail is then inserted in a hole in the upright at L, which, falling into the groove, secures the axle without interfering with its revolution. To make the click-clack, a little bit of wood suspended at D by a short bit of string is made to strike the frame every time the axle revolves. A better arrangement is given here which, will, at any rate, surprise the most insolent cock sparrow till he gets used to it, which he very soon will. A little hammer (D) is made by attaching a knob of hard wood to a bit of *thin* wire or thin watch spring. It must be thin, because it must yield at once after the stroke is given, or it will stop the mill. E is a clock bell, which can be had at any watchmaker's for a shilling, or it may be a toy bell, but these have not much ring in them. It is mounted on a stout wire, and must not be allowed to rest on the frame. The hammer must be arranged so as just to strike, but not rest upon it. It will make a delightful din, like an alarum. H represents a sail sawn out of ¼in. board to something of that shape. It must be rounded not only to fit the holes in the axle, but to allow each sail to be accurately set by being twisted round till the wind seems to act fully upon them all. They must all be turned in the same direction —*i.e.*, the right or left hand edge, as you face the sails, must be set back or forward; not the right of one and left of the other, or they will stand still.

The fantail in this case is a flat tail, like a larger sail let into the back or mortised into the upright, so that its flat sides agree with the sides of the mill. It should be just so large and long as to balance the weight of the sails, thus taking off all possible side strain on the upright pivot. If this is carefully attended to, the mill will turn instantly if the direction of the wind should change.

It may, perhaps, be worth while to explain how this tail keeps the sails in the right position. The wind must act upon their face, and by striking upon the slanting sides of the sails, and glancing off, its reaction drives them round. It matters not what the force is. If a finger is pressed against the sail, and advanced in a straight line, something must yield to its pressure. If the sail were quite flat such pressure would break it, but if twisted half round, the end of the finger pressing against it would compel it to yield sideways, causing it to revolve, and a part of the force applied would be utilised thus in turning it, while part would have no other effect than to strain the sail by pressing it back—tending to break it. Suppose when you set up the mill that the wind is not in front, but strikes sideways, it will not turn the sails, but will press against the flat fantail, and push it away till it has so far turned the mill on its spindle that it can no longer act in this way. By so doing, as the fantail is at the back, the sails will have been brought round till they face the wind, which will, of course, begin to act on them. Then, if the wind vary ever so little, it will again strike on one side of the fantail, producing the same movement as before, so that the effect of this simple addition is to keep the sails always in the position required to meet the wind. In a real mill a fantail large enough to convert it into a weathercock would be an unsightly and cumbrous affair if constructed like the above. It is, therefore, modified, but effects the same result. The general arrangement is given in Fig. 38, and the ingenious toy-maker, if ambitiously disposed, may tax his ingenuity by attaching a similar one to his toy windmill. The fantail is here converted into a set of small sails arranged on an axle, just like the vane wheel of an old-fashioned smoke-jack. It is driven at a great pace when the wind strikes on its face. In an ordinary mill driving three or four pairs of stones these sails are 12ft. in diameter, though from the height at which they are placed they appear quite small to a person standing below and looking up at them. I have shown this part without the framing to render the action clearer. A is the fantail, upon the axle of which (B) is a bevel wheel (C), working into another (D), on an upright axle ;

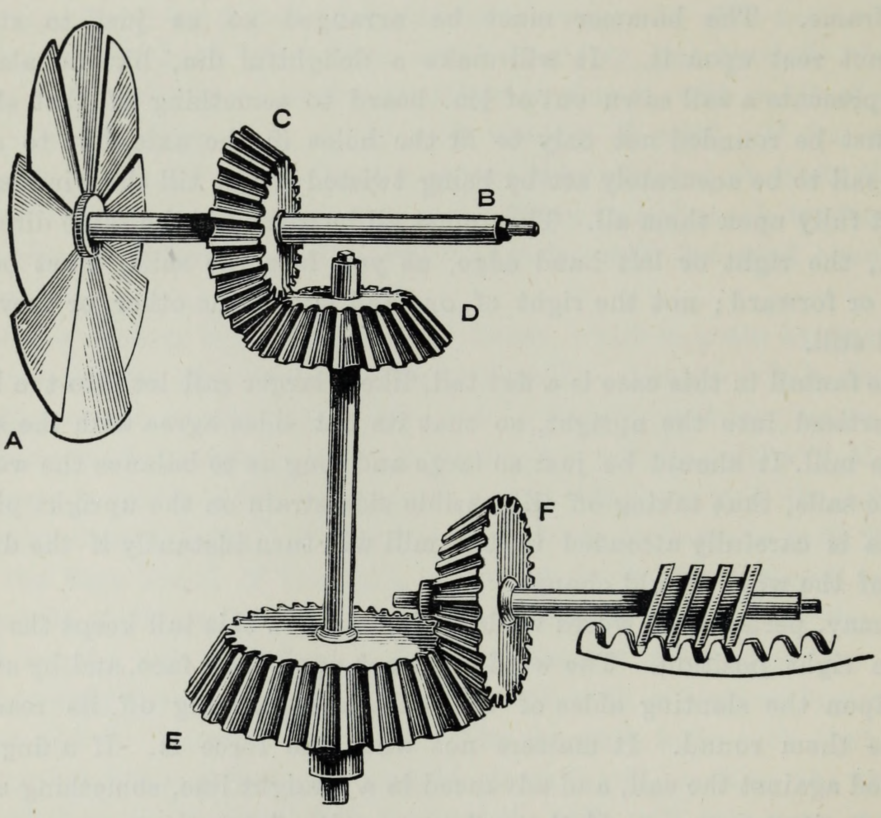


Fig. 38.—Fantail with Bevelled Wheels.

at the bottom of this is another similar wheel (E), and its companion (F), by which the motion is again changed from vertical to horizontal. On the axle of this wheel is a short strong bit of a screw of very coarse pitch, which lies in the cogs of a circular rack running all round the upper part of the mill. As this endless screw revolves it acts with enormous power upon the rack, and turns the mill head round with apparent ease. I would here call the toymaker's attention to the bevel wheel as a means of changing the direction of motion. A face wheel is one with cogs upon the flat of the wheel instead of upon the edge. Sometimes these wheels are like very large bevel wheels, with cogs only extending a couple of inches or so towards the centre of the cone. These are often used in millwork, the cogs being generally of wood let into iron. In the old post mill the steps were necessarily fixed to the floor, and were carried round with the mill.

CHAPTER XI.

LOCOMOTIVE ENGINES.

THE simplest of these will, of course, first demand notice, as for the present we must confine our attention to wooden toys. The essential parts of the ordinary toy locomotive will consist of a stand, carrying the axles of the wheels, a boiler of solid wood, turned to size and shape in the lathe, and a funnel or chimney. To this should, however, be added a smoke box, a dome, and a cab or protection for the driver. These additional parts give a far more realistic appearance to the toy, although otherwise of no real importance. The drawing, Fig. 39, will, I think, be recognised as the normal type of toy engine.

The part marked A is a cylinder of wood, to be neatly turned and smoothed with fine sandpaper. The size is of no great importance, but should be such as to give the whole a handsome appearance, say, 6in. long by 2½in. in diameter. After being turned, a flat place is to be made by the chisel or plane on one side of the cylinder, by which it can be attached to the bottom board. The flat thus made should be about 1¼in. wide on a boiler of the size stated, and the bottom board may then be ⅜in. thick, 8½in. long, and 3in. wide, the extra length allowing of smoke box, with funnel above it, and the cab, of which the bottom will then be 1½in. in length. Plane up neatly on one side, if not on both sides, the bottom board, taking care that the ends are truly square. The ends, moreover, of the boiler must either be cut off in the lathe or marked with a deep notch made by the chisel and then sawn off with a tenon saw to insure their being at right angles to the length of the boiler. Otherwise the additional pieces at the ends cannot possibly be made to fit accurately, and the whole concern will be a muddled, unsatisfactory affair. Both these end pieces should be like that shown at B, but that carrying the funnel should be 1in. thick, the other, called the cab, may be ¼in. only. The latter should stand higher than the other, which need not be

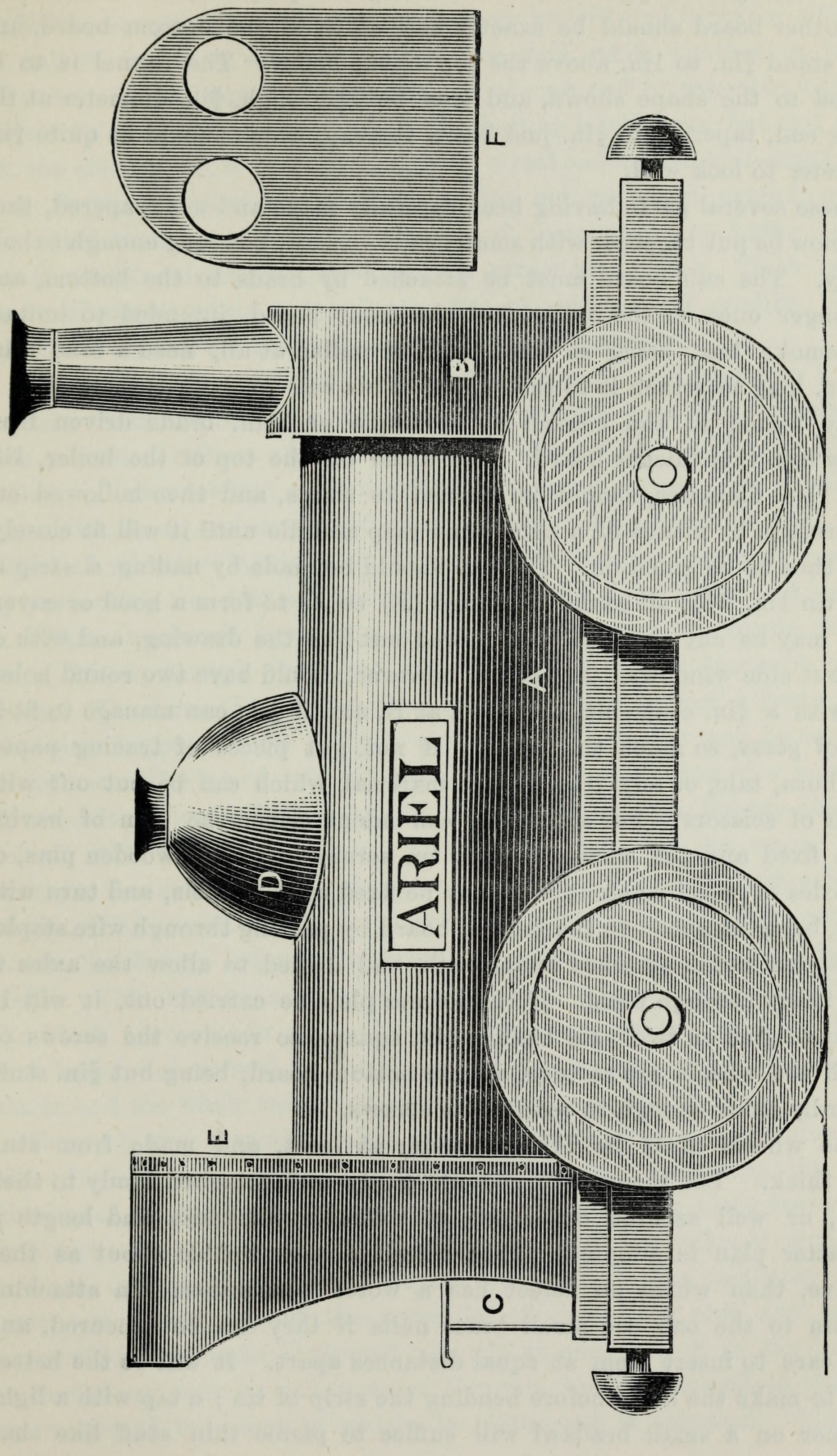


Fig. 39.—Simple Locomotive Engine.

more than ⅜in. to ½in. above the boiler, and project ¼in. on the sides. The other board should be exactly the width of the bottom board, and may stand ¾in. to 1in. above the top of the boiler. The funnel is to be turned to the shape shown, and may be 2½in. high, ¾in. diameter at the lower end, tapering to ½in. just below the cap, which should be quite ¾in. diameter to look well.

These several parts having been carefully made and sandpapered, they may now be put together with small brads—small, but long enough to hold firmly. The cab board must be attached by brads to the bottom, and by longer ones to the boiler, but the front board, intended to imitate the smoke box, being so thick, will, if nailed at all, need a brad 1¾in. or 2in. long to attach it to the boiler. This will not be necessary if it is firmly nailed to the bottom by a couple of 1½in. brads driven from below into this thicker board. The dome on the top of the boiler, 1in. and 1½in. diameter, should be turned to shape, and then hollowed out underneath by means of a half-round rasp and file until it will fit closely. It is then to be glued on. The cab should be made by nailing a strip of thin tin 1in. wide all round the board (E) so as to form a hood or cover. This may be cut straight or hollowed out like the drawing, and with or without side windows. The board, however, should have two round holes, cut with a ⅜in. centrebit, as shown at B, and if you can manage to fit in bits of glass, so much the better; if not, put pieces of tracing paper, thin horn, talc, or any transparent material, which can be cut out with a pair of scissors. For axles you can adopt either the plan of having them fixed and the wheels turning on screws or turned wooden pins, or the axles of wood or stout wire may be fixed to the wheels, and turn with them, being attached to the bottom board by passing through wire staples or wooden blocks attached underneath, and drilled to allow the axles to pass freely through them. If the former plan be carried out, it will be better to glue on two axle beams, ½in. square, to receive the screws on which the wheels are to turn, as the bottom board, being but ⅜in. stuff, is hardly thick enough to receive the screws.

The wheels must be 1¼in. diameter at least, and made from stuff ½in. thick. Let them be turned up nicely and attached firmly to their axles, or well secured on screws of tolerable thickness and length if the latter plan is adopted. Thin wheels always wobble about as they revolve, than which no defect has a worse appearance. In attaching the tin to the cab use small brass nails if they can be procured, and take care to insert them at equal distances apart. It will be the better plan to make the holes before bending the strip of tin; a tap with a light hammer on a small bradawl will suffice to pierce thin stuff like that recommended. Thicker tin may be used, but I would caution the toymaker to remember that if stiff and springy he will find it rather difficult to nail it on, as it will often draw one nail while another is being driven in. Small square blocks, turned at one end to resemble buffers, should be glued on at each end of the bottom board near, but not quite at, the corners, or, if more similarity to a real locomotive be desired, two long strips may first be glued under the bottom board, extending ½in. beyond it at each end, and to the ends of these strips or buffer beams small mushroom-shaped pieces can be attached by glue. Such is the mode of constructing a toy locomotive of rather good quality, but it cannot be considered finished until painted and decorated.

The smoke box should be painted black, as it is always in a real engine ; A should be green, because it is not the iron that is visible in this part of a railway engine, but strips of wood or "lagging" as it is called. These are laid close together like barrel staves, with a layer of felt under them, and are bound over by three or four hoops of iron. The object of all this "lagging" is to retain the heat as much as possible by preventing the cold air from striking on the metal boiler and chilling it. This woodwork is usually painted a rich green, the bands of iron being black, though these are sometimes replaced by hoops of bright brass. The dome (D) is always of bright brass or copper. The wooden one may be painted to imitate copper. The cab (E) may be coloured vermilion. The bit of rail (C) should be made of brass wire polished. The wooden frame will look well of a dark oak, or of a lighter oak tint veined with a darker colour. The wheels may be the same, with, perhaps, the small central circle and a band on the edge both coloured black. The name should be painted on a piece of tin first coloured white, the letters being of a bright vermilion edged on one side with black. This will cause the letters to stand out and appear solid, as the black edge stands as a shadow. It must be all on one side of each letter, not on both, for shadow is cast only in one direction. Buffers black, and the whole varnished afterwards.

The next step towards reality that can be made in a toy engine is to add cylinders, and give motion to the piston-rods. Retaining the parts illustrated in the previous figure (Fig. 39), we must place two turned cylinders on the outside of the boiler, and, for the sake of simplicity and ease in manufacture, they should be made on the oscillating principle, which will prevent the necessity of connecting rods and guides. An oscillating cylinder is pivoted on a pin at one end, or in the middle, so that it can rock up and down on this pin, and accommodate itself to the motion of the crank to which its piston-rod is attached. This rod in the wooden model will be simply of wire, and no piston will be attached to it—the cylinders, in such case, not requiring to be bored, except with a small hole to allow free movement of the wire.

Fig. 40 represents the complete engine, to which a few additional parts have been added besides the cylinder. B is an imitation safety valve; C, the starting lever; D, the reversing lever; E, gauge cocks. The wheels are also linked together by side or coupling rods (F) giving another source of motion, because the more visible the movement of its parts the more like a real engine will the toy be. In Fig. 41, p. 97, the cylinder is represented by A. It is about 1¼in. long by ¾in. diameter, but may be larger or smaller, according to the size of the complete model. At one end is an imitation gland or stuffing box, through the centre of which the piston-rod moves. These cylinders, being solid, are easy to turn. Put a bit of deal or beech of suitable size on a prong chuck, and use the back centre to keep it in place. Place the rest nearly close—the top of the T a little below the line of centres—rough down with the gouge, and finish with the chisel, producing in the first place merely a plain smooth cylinder. Then turn down the small part to imitate the gland, making it on the right-hand end of the cylinder next to the back poppet. Turn it down merely to a smaller size in the first place, using the chisel to face up the end nicely. Then cut out a notch, and with the chisel angle work it right and left to widen it, finishing with a very narrow chisel or parting tool, and smoothing with a bit of glass cloth folded sharply, or with a small file. Lastly, cut it off at the chuck end. To do this neatly use the sharp angle of the chisel, and cut a deep notch. Continue to widen this, keeping the cylinder end upright and true as you deepen the cut, and sloping the other to give you plenty of room to work the chisel.

It is as well in all cases like this, where you have to make two things alike and of equal size, to turn them together out of the same piece. In the present instance, if the original piece of stuff is made long enough to produce both cylinders with a half inch, or thereabouts, to spare, you may make glands at each end as much alike as possible, and then divide the piece exactly in the centre, forming at this division the ends of the two cylinders instead of one only, working as before directed. Then, while enough substance remains to prevent the parts breaking asunder, finish the cylinder ends with sandpaper, and then give the *coup de grâce*, cutting off where necessary, but taking care to work down all the three parts ready for the final severance, *i.e.*, the stuffing boxes and the cylinder bottoms. The right-hand gland may be worked close to the point of the back poppet, as the mark made by this point will be just where the hole must be drilled. The two places of severance will then only remain, and little difficulty will be found if care is taken. In B of

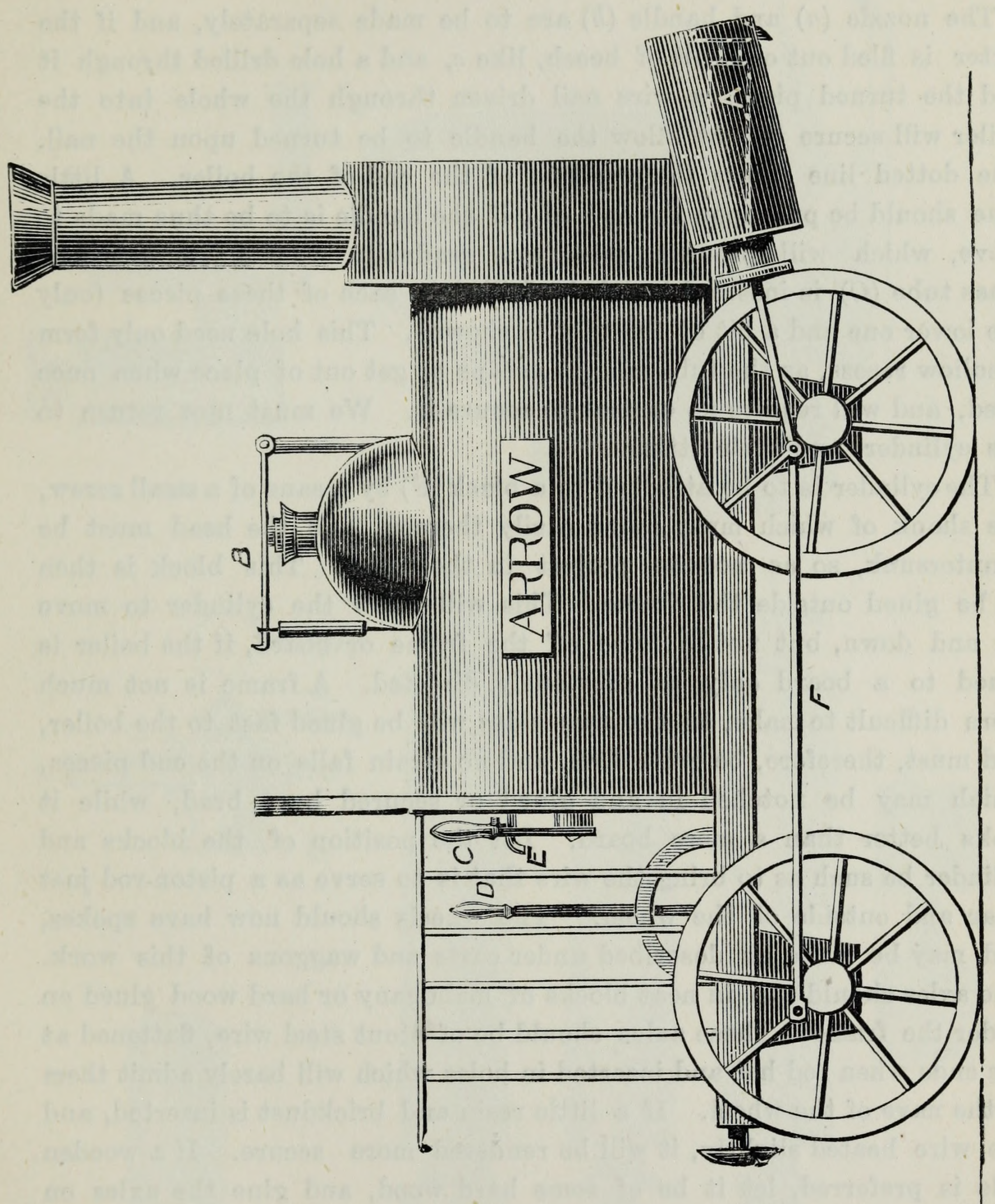


Fig. 40.—Locomotive Engine, with Oscillating Cylinders.

Fig. 41 is represented the two cylinders in process of construction, showing how they are to be worked simultaneously, 1, 2, 3, 4 illustrating them in several stages. The glass gauge (C) if also added, may be made very easily of one of the small bits of quill tubing sold by chemists, or a bit of quill from the wing of a goose may be used as a substitute, and will do as well. Turn two little pieces of wood to act as sockets, and imitate the brass taps like D.

The nozzle (*a*) and handle (*b*) are to be made separately, and if the latter is filed out of a bit of beech, like *c*, and a hole drilled through it and the turned piece, a wire nail driven through the whole into the boiler will secure it, but allow the handle to be turned upon the nail. The dotted line shows the position of the end of the boiler. A little glue should be put upon the end of *c* if the handle is to be thus made to move, which will prevent this from gradually working loose. The glass tube (C) is inserted in a hole drilled in each of these pieces (only the lower one and a bit of the tube is shown). This hole need only form a hollow recess, as the tube cannot escape or get out of place when once fixed, and will require no cement to secure it. We must now return to the cylinders and their fittings.

The cylinder is to be attached to a block (F) by means of a small screw, the shank of which must move easily thereon, and the head must be countersunk, so as not to project in the least. This block is then to be glued outside the frame. This will allow the cylinder to move up and down, but not to come off the frame or board, if the boiler is glued to a board only, as previously directed. A frame is not much more difficult to make, as the two sides will be glued fast to the boiler, and must, therefore, be quite firm, and no strain falls on the end pieces, which may be notched in and glued or secured by a brad, while it looks better than a mere board. Let the position of the blocks and cylinder be such as to bring the wire that is to serve as a piston-rod just clear and outside of the wheel. The wheels should now have spokes, and may be made as described under carts and waggons of this work. The axles should run in neat blocks of mahogany or hard wood glued on under the frame. These axles should be of stout steel wire, flattened at the ends when red hot and inserted in holes which will barely admit them in the nave of the wheel. If a little resin and brickdust is inserted, and the wire heated slightly, it will be rendered more secure. If a wooden axle is preferred, let it be of some hard wood, and glue the axles on tightly. On one of the spokes of the wheel insert a small screw head, outwards, as a driving pin on which to centre the piston-rod, which must be bent into a loop to fit the screw easily. On the same screw, also, centre the side rod—a similar pin, in exactly the same relative position, being fixed in a spoke of the second wheel. Neither pin should be more than ½in. from the centre of the wheel, or the stroke will be too long and

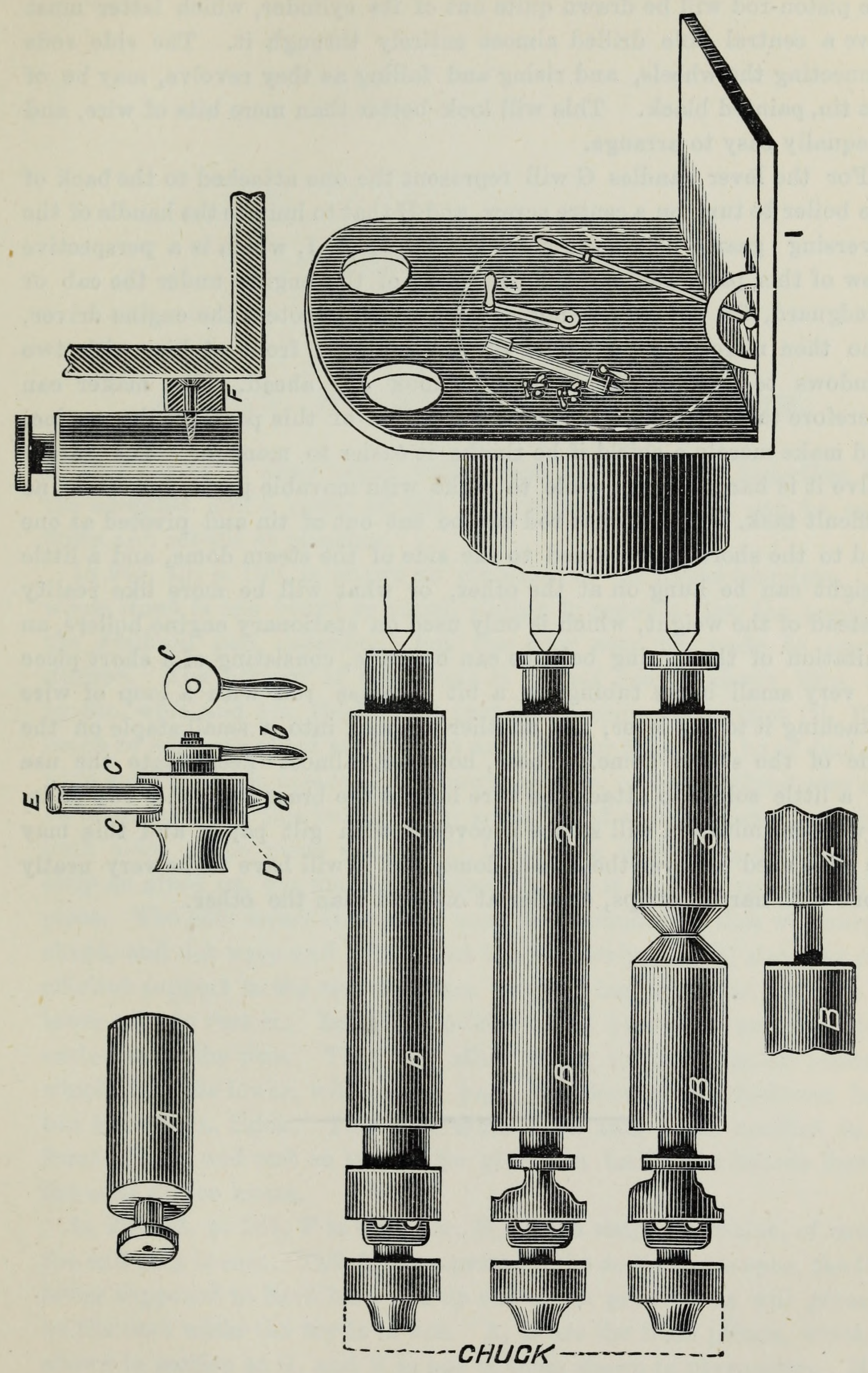


FIG. 41.—SECTIONAL PARTS OF LOCOMOTIVE ENGINE.

the piston-rod will be drawn quite out of its cylinder, which latter must have a central hole drilled almost entirely through it. The side rods connecting the wheels, and rising and falling as they revolve, may be of flat tin, painted black. This will look better than mere bits of wire, and is equally easy to arrange.

For the lever handles G will represent the one attached to the back of the boiler to turn on a centre screw, and H that to imitate the handle of the reversing gear. These are placed as shown at I, which is a perspective view of this part, representing the back of the engine under the cab or windguard, for the cab is not always used to protect the engine driver, who then merely has a shield of flat plate in front of him with two windows to enable him to keep a look out ahead. The maker can therefore take his choice in the construction of this part of the engine, and make merely a shield if he thinks it easier to manage. The safety valve it is hardly worth while to make with movable parts, but it is no difficult task. The top flat rod can be cut out of tin and pivoted at one end to the short pillar glued to the side of the steam dome, and a little weight can be hung on at the other, or what will be more like reality instead of the weight, which is only used on stationary engine boilers, an imitation of the spring balance can be made, consisting of a short piece of very small brass tubing, or a bit of brass rod with a loop of wire attaching it to the lever, and another to hook into a small staple on the side of the steam dome. These, however, almost necessitate the use of a little solder to attach the wire loop to the brass rod at its two ends. A wooden imitation will suffice if covered with gilt paper, and this may be also used to cover the steam dome, but it will have to be very neatly done with narrow strips, smaller at one end than the other.

CHAPTER XII.

DOLL'S HOUSE AND FURNITURE.

In this chapter I shall begin with house building, and, departing from the accepted doll's house of the day, describe one that can be pulled down and rebuilt at pleasure.

In Fig. 42, p. 100, is shown an elevation of the house complete. The whole front is one board or panel, sliding in grooves like the panels of the windmill last described, but the door may be made to open if desired. The bottom of the house is a deal board, about 18in. long by 9in. wide and ½in. thick. To prevent warping, the strips (B, B) of beech or ash, are glued across it at each end, or they may be of deal, ½in. wide and ⅜in. thick, attached by screws, or glue, or both. Great care must be taken to make this bottom truly square, and also to plane it nicely on both sides. The piece seen at D, forming a door step, may also be a strip so glued on, but made to project ½in., or it may be merely a short piece. The sole object is to get a good firm foundation that will keep its shape, and not warp and twist; but the two strips (B, B) also give more efficient support to the corner pillars by allowing a deeper hole for the lower pins to rest in. Let these pillars be of ½in. stuff, and 15in. long, exclusive of the pins. This will allow of an upper room or bedroom, which, like the lower, will be 7in. high, the floor of the bedroom being but ¼in. or ⅜in. thick. This floor must slide into cross notches in the front pillars, and rest on two strips glued on inside the boards forming the ends of the house.

In Fig. 43, p. 101, F is the floor, H, H the strips, of which, of course, the end only is seen. This figure represents the doll's house open, the front being supposed to have been slid up out of its grooves, as will generally be the case while the toy is in use. A, B are the front pillars, which are shown in section at G, and K is one of them shown in perspective; M, M are those at the back, the others crossing them, and concealed by the roof, being (as in the mill) the top frame, half lapped at the corners, to make it level on the top. The bottom board should project a little all round, say, ½in., which will give 17in. as the length of the rooms inside. This doll's house will take furniture large enough to be strong and durable, but size is, of course, of no importance if the proportion of the

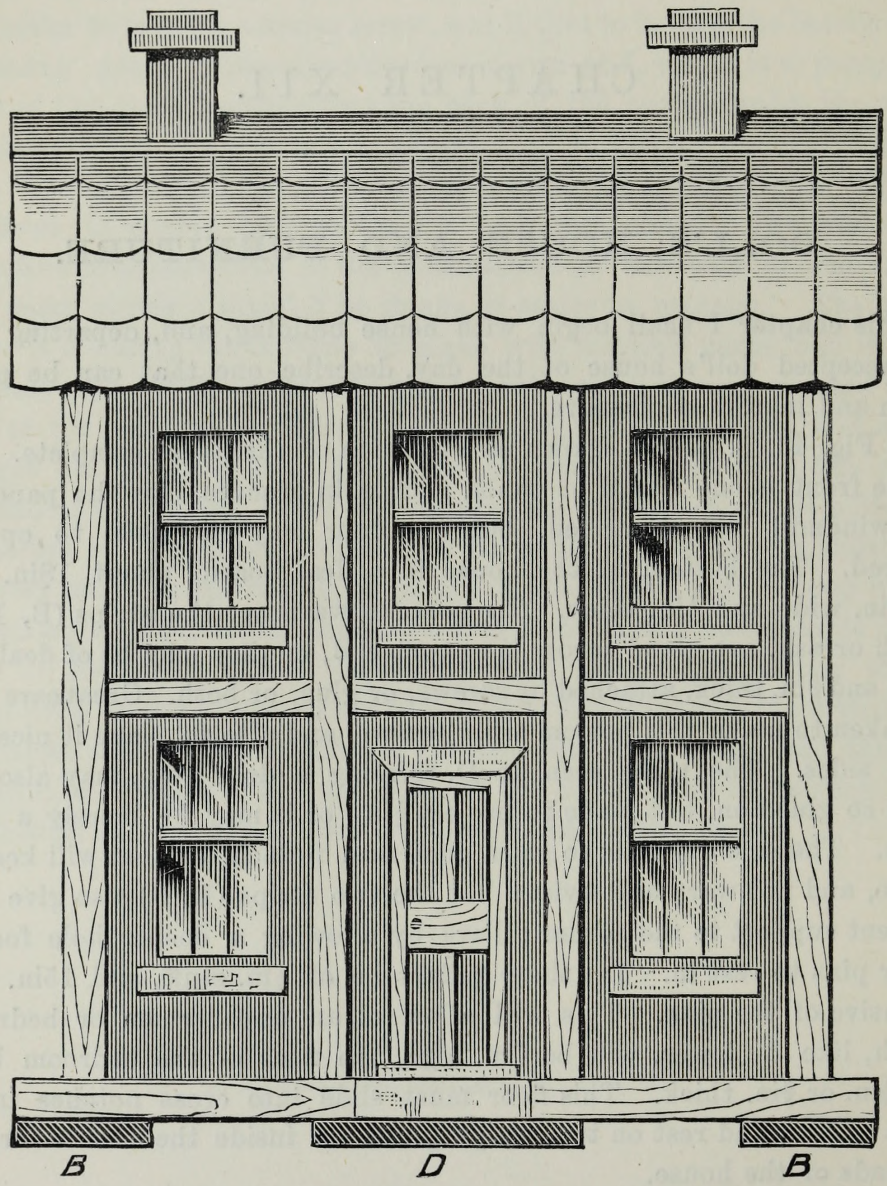


Fig. 42.—Front View of Doll's House.

different parts be attended to sufficiently to give it a nice appearance. But if it be made very small the rooms will not admit the insertion of even children's hands with the freedom necessary to allow them to move about the dolls and their furniture. The directions given in the description of the windmill ought to suffice to make quite clear the method of framing and fitting the doll's house. The four side posts are capped with others forming a top frame, and the front and sides slide in like panels. The roof is made with two gable ends (see Fig. 44, p. 102), the

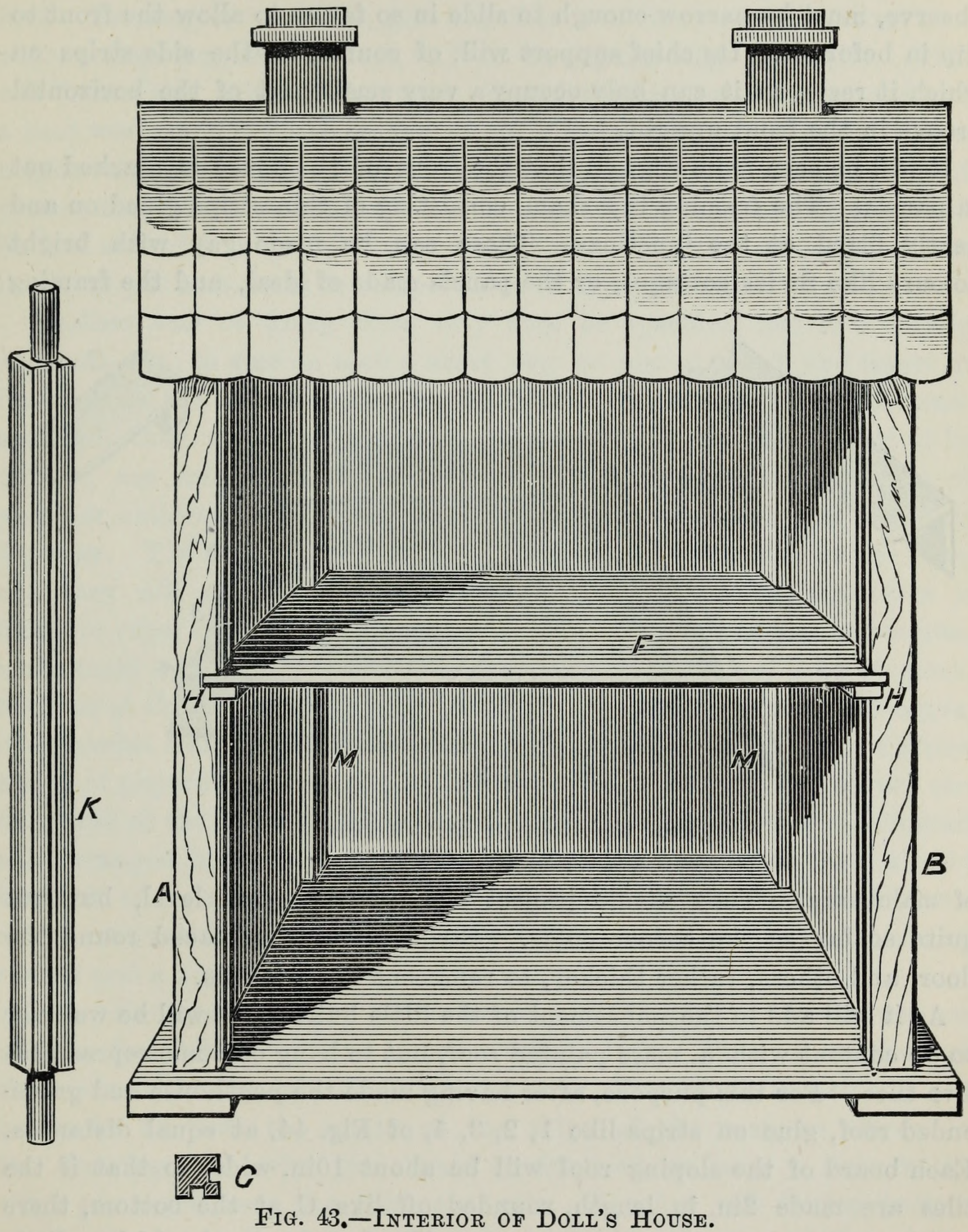


FIG. 43.—INTERIOR OF DOLL'S HOUSE.

width of span allowing it to project and overhang the front and back of the house to form eaves, which prevent it also from falling off, but this may be further checked by cutting the triangular pieces which form the ends, as at B, with a pin or pins projecting below to fit into holes in the cross or tie beam below it. When in use the roof is first removed, then the top front tie beam. The front panel is then slid out, the cross beam and roof replaced, holding the now open house firmly together. It is stiffened also to some extent by the floor or horizontal partition, which, observe, must be narrow enough to slide in so far as to allow the front to slip in before it. Its chief support will, of course, be the side strips on which it rests, as it can only occupy a very small part of the horizontal groove in the front upright.

It will be seen from Fig. 42 that the front of the house is marked out in panels. The framing is a sham, consisting of thin strips glued on and neatly fitted at the junctions. These can be made gay with bright colours like Swiss cottages, or the panels made of deal, and the framing of mahogany. They should project above the general level, but not quite so far as the corner posts. Strips should be placed round the door, and others, rather thicker, to represent window sills.

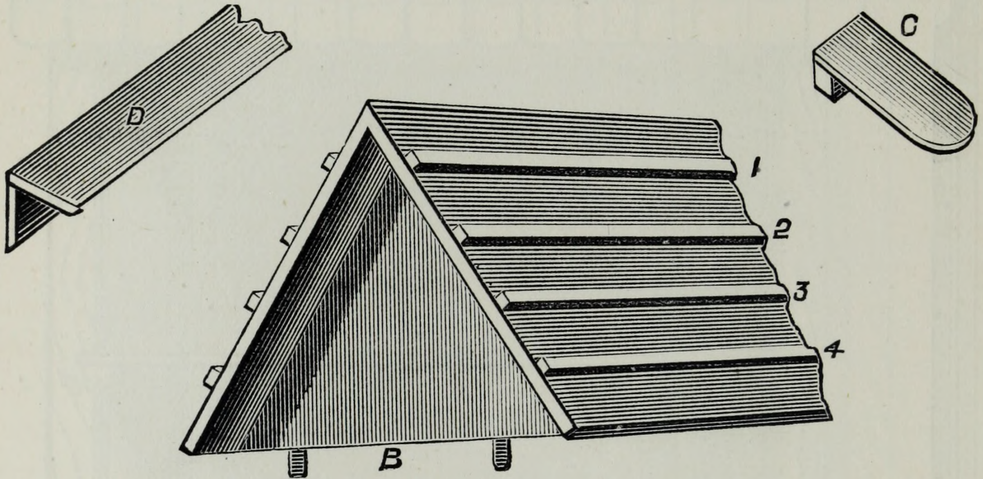


Fig. 44.—Roof of Doll's House.

As it will add to the amusement of the little builders, it will be well not to be content with a mere painted roof, but to hang on some representative tiles. For this purpose, after having made the penthouse and gable-ended roof, glue on strips like 1, 2, 3, 4, of Fig. 44, at equal distances. Each board of the sloping roof will be about 10in. wide, so that if the tiles are made 2in. in length, rounded off like C at the bottom, there will be just room to hang on five rows. The lower ones should be a little longer, so as to overhang the eaves. Each row must just overlap the one below it. Every single tile, made of the thinnest wood procurable (veneering material by preference), is to have glued across it a little strip of wood, as shown at C, which will rest upon the strips glued upon the roof; thus, beginning at the lowest row forming the eaves, they will be hung on one by one till all have been placed. The top strip, however, it will be noticed, is not at the extreme edge of the roof, so that above the last row of tiles a narrow space will be unoccupied on both sides of the roof. To complete matters, glue together two narrow strips, about ½in. wide, and as long as the house, to form an angular ridge piece (D). This will form a cap, covering the upper edge of the last row of tiles, and put a neat workmanlike finish to the whole. Paint this and also the tiles a bright vermilion. The latter should not exceed an inch in width. If of veneer, they can be easily cut out with a penknife, especially if the wood be first soaked in water and shaped while wet. The tiles so cut should be bound or put in a press to compel them to dry quite flat.

Another way of fixing them may here be specified, but it is hardly as good—viz., to glue on each a short peg or pin of wood, and insert in holes made for that purpose in the board beneath. But small pins although they would answer with older children who have learnt to be careful, are sure to get broken off under the too eager manipulation of younger children, who have more difficulty in putting work like this together. The strips cannot well be broken off in hanging on the tiles, and they will secure them equally well. If the toymaker's patience is likely to rebel at having fifty of these tiles to make, he can, of course, make them larger and fewer in number. The windows are to be of glass, fixed on at the back by glueing strips of stout paper round the edges, or a wooden frame to keep it in place. It can then be divided by narrow strips of paper into panes, or, as is often done, a piece of coarse net can be affixed at the back. There should also be pieces of bright coloured silk arranged inside to look like curtains, and in one or two there should be a bit of thin calico, white or otherwise, to imitate blinds half drawn down. Attention to these apparently trifling details will give an air of reality and a nice finish to the work.

The chimneys are mere solid blocks, either shaped as shown, or with a flat bit of square board, rather larger than a section of the main chimney, glued on at the top. The block is notched out below to fit over the angle of the ridge of the roof, as shown in the drawings. A wire pin should be inserted to enter a hole in the ridge piece and keep the chimneys safe. Nothing will better imitate smoke than a tuft of cotton wool, especially if some black or grey wool be mixed with the white. If the toymaker be a neat hand with a paint brush, the whole house should be got up in red, and the mortar lines picked out in white. Window sills to be quite white, and a narrow line of black round the windows. Steps of the door also white, and frame black. In painting toys we must not, as we should in a picture, aim at gradation of tint and delicacy of colour, but use such as contrast strongly. The main and cross timbers, however, taking up, as they do, a large portion of the front of the house, will look better if coloured a rich brown, especially if lined with jet black at the edges. But this lining with paint is not very easy work, as it needs a small brush and very steady hand to do it well. In larger work the brush has very long hairs, which lie flat on the surface to be painted, and, being filled with tolerably fluid colour, the brush is dragged along steadily, leaving, snail-like, its shiny track behind it. Lines picked out on carriages are thus drawn. Dragging a fine brush in this way the toymaker may succeed, but a little practice should first be made upon waste materials.

In the construction of furniture for the doll's house even small sprigs and brads can hardly be used, and we have to rely upon glue to hold the pieces together, so that careful attention should be paid to the section on this subject, and if the directions are attended to there should be no difficulty. For our present work we shall need thin stuff only. The bulk of the pieces need be no more than $\frac{1}{8}$in. thick, and $\frac{1}{4}$in. will be the thickness of our heaviest stuff. Some will be planed down to $\frac{1}{16}$in., which is about the thinnest board we can make use of. But in nothing more than in doll's furniture should clumsiness be avoided, and neat work requires thin light stuff.

The intsructions for making the furniture will be confined to a few of the principal articles, as the same character of work prevails throughout, and anyone who can construct one or two pieces of furniture can make others with little difficulty. As the size of the furniture to be made must so entirely depend upon that of the house and on the number of articles proposed to be placed in it, no directions on that point can be given. In regard, however, to the framework of these miniature suites, there is this difficulty, that one can hardly cut a mortice and tenon in very thin material, so must manage to connect the parts in some other way. In a good London tool shop a chisel as small as $\frac{1}{8}$in. or even $\frac{1}{16}$in. in the edge could probably be purchased, elsewhere it would be difficult to procure one of $\frac{1}{4}$in., and this, of course, will decide the size of the mortice. Nevertheless, with a drill a still smaller mortice may be managed by making two or three holes in a line, and with a penknife throwing them all into one. This, however, is hardly necessary, and in very small work the better plan is to drill one or two small holes, and use bits of pins for nails to hold the parts together while the glue is drying, for glue must in all cases be used in addition.

To make a table, plane up some strips of wood of, say, $\frac{1}{4}$in. square, to form legs, and some for the top frame, $\frac{1}{8}$in. thick or less, and $\frac{3}{8}$in. wide. Cut off from these four broad pieces of equal length, or two short and two a little longer, if the table is to be oblong for the dining room. Take great care to square the ends truly, have glue, boiling hot, close at hand, and some fine twine or strong thread (not cotton). Lay the pieces in position to form an oblong frame, and see whether they fit nicely, then give a touch of glue to each, place in position, and tie securely, or slip over them an indiarubber band. Cut the legs of the requisite length, and when ready, glue each into its corner inside the frame, which will be easy, if the latter is just tied or secured, and is lying on its edge. The legs are to stand up in the air, and not to occupy their usual position till dry. If other tables are needed make these also so far, as it is always better not to complete a thing of this kind out and out, and then to begin another, but to carry two or more to the same degree of completeness, and then afterwards finish all together. The table will appear like Fig. 45.

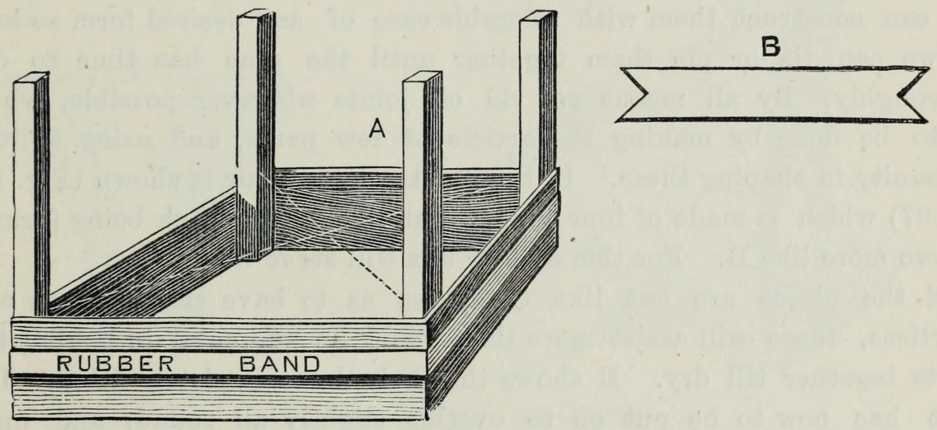


Fig. 45.—Frame of Table.

The only possible difficulty to be met with at this point is the falling inward of the legs before the glue can dry. These accidents may generally be prevented by simple means. Cut out two little pieces like B, notched at the ends, and just long enough to fit from corner to corner inside the legs and frame. Drop them in at the dotted lines, so as to bear against the legs, and they will hold them firmly; but take care not to make them tight enough to force open the frame. Leave all to dry, and then with a penknife clean off any bits of glue, and, turning the table so as to stand upon its legs, see that it bears equally on them all and stands perfectly. If not, correct with a sharp knife where necessary. All that remains will be to make the top—oval, oblong, or square, as is wished. This must be of thin stuff very nicely faced on one side. It is seldom that it is faced at all on the other. The top of an old cigar box provides famous stuff for a table top, and can be polished or varnished. If plain white wood be used for the table top the wood stains now so largely used will avail for the imitation of oak, walnut, or mahogany. They should not be used in excess, as a light coat generally looks the best. Then with thin glue give a coat of size, and when quite dry varnish with hard white spirit or oak varnish ; the first is the better of the two for such small articles.

To make a chair we have a choice of several plans more or less like the reality. These small and light articles are dependent on glue for their stability, and need no proper jointing to unite the parts, so that we can construct them with tolerable ease of any desired form so long as we can tie or pin them together until the glue has time to dry thoroughly. By all means get rid of joints wherever possible, which is to be done by making the article of few parts, and using a little ingenuity in shaping these. In the illustration a chair is shown (Fig. 46, p. 107) which is made of four pieces, cut like A, the back being formed of two more like B. For this a cigar box will serve well.

If the pieces are cut like C, D, so as to have small tenons and mortices, these will assist more than would be supposed in holding the parts together till dry. E shows the chair thus completely fitted. The seat has now to be put on to overlap slightly all round, and upon this are to be glued the two pieces which form the back. A top cross rail fitting in the notch F, and a second at G, will complete it. The chair thus constructed is shown in the drawing, and if a bit of bright red velvet be gummed on the seat H, and the different parts are smooth, so as to admit of a coat of varnish, a very neat and effective article of doll's furniture will result. If, as is probable, three or four are needed, cut out as many pieces of each shape illustrated as are required, pinching them together in a vice and filing all together. The chairs will then match each other as they ought to do. This is a much better and more workmanlike plan than to construct one before commencing the next. Such is one mode of chair making, and, perhaps, the best, inasmuch as the result is not only very easily attained, but it is a tolerably strong little toy, more so than when framed up out of many small pieces, with each leg separately glued in, for these are always the parts which in dolls' furniture are unduly weak, and if we can combine these with the top frame instead of making them as separate pieces, we shall, undoubtedly gain in respect of their stability. Precisely the same plan can be followed in making a sofa, but it should be varied slightly by using only a pair of similar pieces forming together four legs and uniting these by longitudinal strips. This modification may likewise be followed in chairs if preferred, with but little, if any, deterioration of their strength.

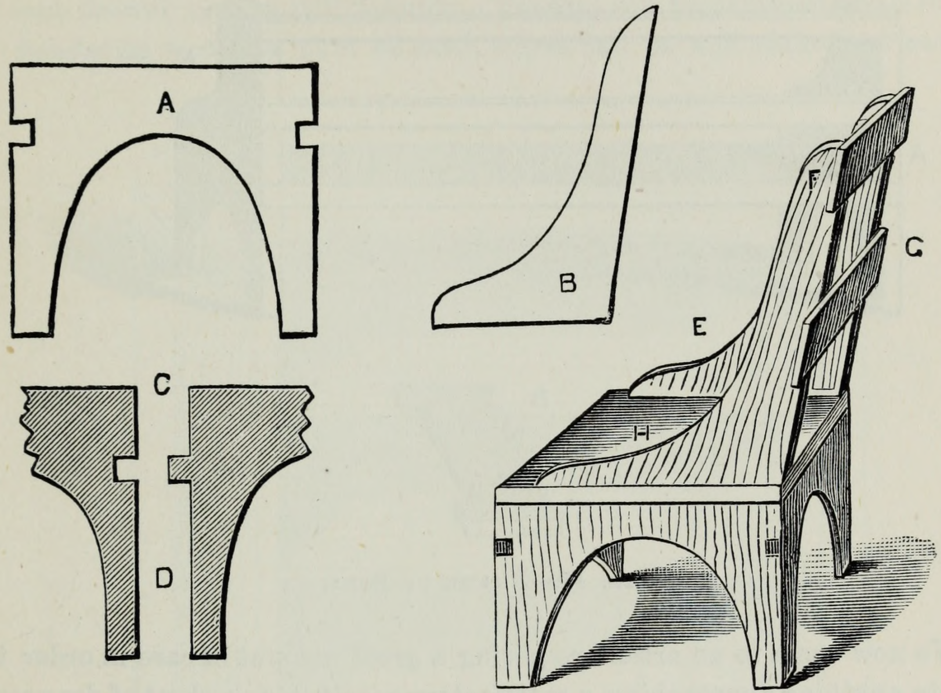


FIG. 46.—DETAILS OF CHAIR.

Fig. 47, p. 108, represents such a sofa, of which the ends (A, A) being shaped as shown, form both arms and legs, and are connected by the seat and the two back rails, which are notched into them and glued. B is one end of the seat, and will serve to show how the latter is let into the ends by two small tenons, which add much to the stability of the whole article. The seat can, if preferred, slide into a groove in each of the end pieces if these are thick enough; and it can be covered, like that of the chair, with silk or velvet, and still further assimilated to reality by a stuffing of wool. This is an excellent way of making seats of larger size for household use, and is also adapted for church seats, of which the ends should be thick oak, nicely moulded round the edge, and in such case only one broader rail is used at the back. For study use these may be made by the amateur without much difficulty, and the tenons may be carried through, and have wedges driven in on the outside of the standards; thus made they are in a manner portable, as it is easy to drive out the wedges and separate the parts into so many flat pieces. The back should not be so upright as that of the doll's sofa, represented here.

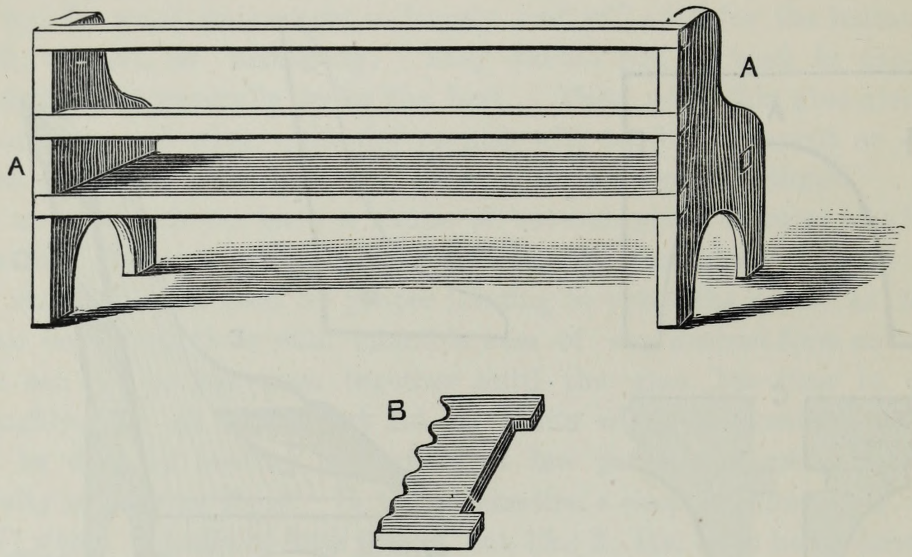


Fig. 47.—Frame of Sofa.

We now come to an article requiring a great amount of care in order to attain anything approaching a satisfactory result, viz., a chest of drawers; and after I have described the way to make it, I shall dismiss the subject, leaving other pieces of furniture to the ingenuity of the reader who wishes to exercise his skill on these matters. Beyond all question the chests of drawers sold in the cheaper sets of dolls' furniture are as wretched specimens as can be found anywhere, the front of each drawer by no means representing the length of that of which it is a part, and no attempt at a fit is made.

The material selected must be thin, or the chest will be clumsy, and here again the cigar box will be found to afford the requisite boards. The ends, however, of the cigar box being of thicker stuff, must be rejected. At the same time I may call attention to the fact of this thicker stuff. In most boxes it will be noticed that it is usual to make the ends stouter than the sides which are nailed to it, a better hold for the nails being thereby obtained. In the present case, if large enough—say about $2\frac{1}{2}$in. square by 1in. deep—we can follow the same plan, as it enables us to use much thinner stuff for the top and front than could otherwise be managed—say $\frac{1}{16}$in. thick for the two sides, and the remainder $\frac{1}{32}$in., or half the thickness. Pieces $\frac{1}{16}$in. can be made to hold small sprigs or bits of needles and pins to help the glue, at any rate until the latter is dry. Fig. 48 represents the outer case or carcase of such a chest, 2½in. high, 2in. wide, and 1in. deep, inside measure. The sides are $\frac{1}{16}$in., the remainder, including the divisions between the drawers, $\frac{1}{32}$in., which is the thinnest stuff that can well be used in this article; but the bottom of each drawer may be still thinner. Veneers can be obtained of all sorts of handsome wood as thin as card, which can be well soaked in water, cut with a knife into little planks while wet, and screwed in a press or put under a heavy weight to dry, when they will be found quite flat and fit to use. Being sawn to uniform thickness, they answer well for work of small size, and will take a fine polish after being sandpapered and brushed with weak glue or patent size, and dried.

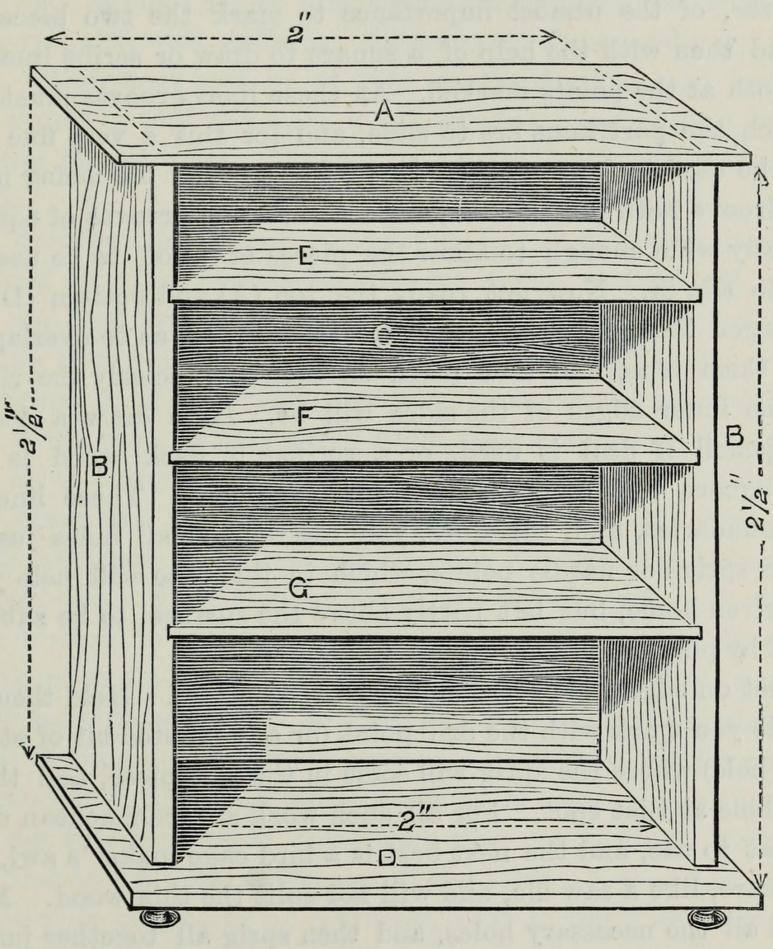


Fig. 48.—Sectional View of Chest of Drawers.

Cut out first the ends (B, B) of $\frac{1}{16}$in. stuff, and take great care to true them up with a plane or a chisel, square and exact to size; being specially attentive to the edges, which must be at right angles to the sides. Here again it will be the best plan to set a plane bottom up on the bench, and taking the wood in hand, reverse the process by moving the wood over the sole of the tool, which must be keen as a razor and very finely set. Now make up your mind how many drawers you are likely to have patience to make, and prick off with compasses on these side pieces the exact places for the several divisions. It is usual to make the lower drawers rather deeper than the upper, but this is of no importance. It is, however, of the utmost importance to mark the two pieces exactly alike, and then with the help of a square to draw or scribe lines straight across both at the points marked. At these lines grooves must be made, into which the partitions are to slide, and for this a very fine saw or a file can be used, a key-warding file or knife edged file being most suitable. Groove both pieces alike, and make all the grooves of equal depth, and exactly wide enough to allow the pieces of wood to be used as partitions to slip in. Now get ready the top (A) and bottom (D), cutting these larger than the size of the carcase itself, so as to overlap. Plane and file them true, and then mark on each in precisely the right place where the inner edges of the sides will be. Here draw a decided line with a pencil if deal is used, or a scriber if dark wood is selected, using a square very carefully to insure exactness. These lines are the inside boundaries, and, therefore, you can drill small holes just outside them for sprigs or needle points, which in this case will help you, even if not driven home, but left partly above the surface, to be subsequently removed by pliers.

Now set on edge one of the sides and the bottom. Hold them in position while you mark with the drill point (or any pointed bit of steel put in the drill hole) where the sprig will come in the side piece, and then make a small hole at that spot. For all such work an archimedean drill stock is the best to use, and the next best is a bird cage maker's awl, which is three-square, like a saw-file, and will not split the thin wood. Mark this, and drill all the necessary holes, and then sprig all together just enough to hold, and see if all is square and true, fit for glueing. Although the top and bottom should overlap in front and at the sides, all may be flush at the back, and this will facilitate putting the parts together in the manner described, because all the four pieces can be stood on edge upon the table or bench, and thus made to fall into place more easily than if the top and bottom were not thus flush. If all looks right, pull apart, and with boiling glue touch the edges and immediately press together again, tapping the sprigs with a light hammer to drive them home, or, at any rate, to make them take a closer hold. Now, also, set the frame true by a square, so that when dry it will be straight and accurate, as it should be. If this is not done the rest of your work will be most difficult, and the whole affair thoroughly unsatisfactory. The partitions between the drawers must now occupy attention. It is better to leave these until all the rest is dry, and while this is taking place they can be cut out in readiness. If the work hitherto has been well done, these pieces will be exactly alike, but it is not absolutely necessary to work them up together. Care must be taken that the ends are square to the sides, and they must be long enough to fit and slide into the grooves without much pressure, yet still with sufficient tightness to show hardly a crack when in place. They need not be so wide as the chest is deep, but will be better if nearly of that width, as it will provide more efficient surface for each drawer to rest upon. Three-quarters the depth of the chest will do very well.

These divisions being put in and glued, and the back made of thin stuff, glued on, the carcase should be neatly cleaned off, and sand papered, and if of veneer or cedar, can now be polished if desired. But the drawers have yet to be made, which in these small chests are merely shallow boxes or trays. They demand, however, very special care, or they will never work as they ought to do. In a real drawer I may mention that the sides always project below the bottom, so that the drawer may slide on these two narrow edges, while the bottom is clear and does not touch anywhere. You can manage this if preferred, though it is of little importance. First cut out the fronts, fitting them, each singly, into the place destined to receive them. The better the fit the nicer will the chest look when finished, therefore take all possible care, and mark a corner of each drawer front, so that you may make no mistake subsequently as to the position it is to occupy. In cutting out the ends of the drawer remember that you must make them short enough to allow the front of the drawer to go in quite flush when in its place. Allow, therefore, for this and for the thickness of the back. I need hardly describe the precise mode of glueing up a drawer, as it is but a repetition of what has already been done, only remember to glue the sides *inside* the front, as it is sketched at K of drawing (Fig. 49, p. 112), and either quite flush with it or slightly inside it. The back must be flush in any case. Now with regard to the bottom we must allow for its thickness in cutting out the two ends of the drawer, and these must not be even in that case with the lower edge of the drawer front, if the drawer is to rest upon the bottom. But if made to rest on the edges of the end pieces as in a real drawer, then in that case let these pieces be truly flush with the front. At L is represented the corner of a drawer thus made which can be compared with H. Of course, as the drawers are of different sizes, each must be made quite independently, and each must be carefully and separately fitted. For handles to the finished drawers, small brass nails will do driven half in, but if a lathe is at hand, they can be turned of box, ivory, or wood. Four little knobs should also be added for legs, though these can be cut in one with the sides if preferred, by hollowing out slightly the bottom edge of each, so as to leave projections to serve the same purpose.

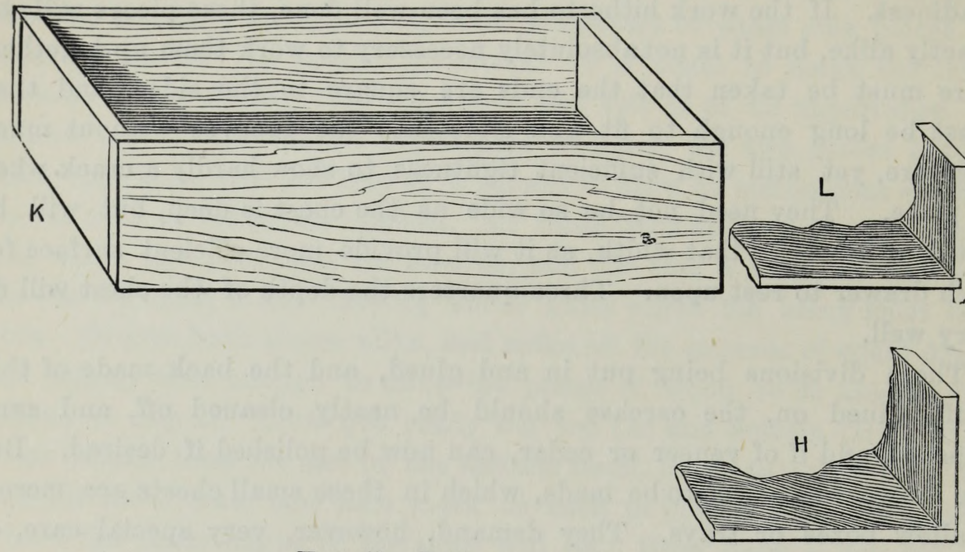


FIG. 49.—DRAWER FOR CHEST.

CHAPTER XIII.

TOYS WORKED BY SAND.—PRINCIPLES OF CONSTRUCTION.

FOR toys of a higher class than any I have as yet described—those with mechanical details—metal will be very generally employed, either alone, or in combination with wood. There is, however, one self-acting toy which is worthy of mention, in which the prime mover is sand falling on the vanes of a wheel from a receptacle placed above it. The Leotards and similar moving figures are thus made, and are of very simple construction, although the movements of the figure or figures are natural and lifelike if the toy be made with care. Prepare, first of all, a box of thin board, like those used to contain puzzles, toy bricks, dissected maps, and similar articles. Let it be about 9in. or a foot square, and 1in. to 1½in. deep; not less than the latter if a glass is to be fitted in over the figure, which is the best plan. If a glass is to be used, the bottom of the box, or that part forming the back when it is set on end, as it will be eventually, ought to slide in by means of a groove, so that the interior may be got at if at any time the machinery should be out of order. The front glass ought also to slide in a groove, and there must be in addition a false bottom or partition to which the sides and ends may be nailed and glued. A (Fig. 50, p. 114) is a section across the box, and B an enlarged perspective view, in which one side is removed to show clearly this arrangement. The glass need not stand more than ⅜in. to ½in. away from the middle partition. These sliding parts, viz., the glass and back, need not be so fitted, although it will be the best way to make them thus. If considered easier, the glass can be puttied into a neat rebate, and the back nailed or glued on; but in case of a breakage or some little defect in the moving parts, it will then be impossible to get at the interior without breaking the back. All machinery should be so constructed that it may be easily taken to pieces for cleaning or repair, and, wherever it is possible so to plan it, each individual part should be get-at-able without having to disarrange the rest. You will find, for example, many watches now made with little plates to cover each separate wheel, like C, the upper or under pivot, as the case may be, centreing in this plate so that each of the wheels can be taken out independently of others. In home work of a similar kind I would suggest a like expedient, as considerably facilitating the manufacture of all kinds of mechanical toys. Let another rule be likewise followed, as it will save many a failure. Think out a design well before commencing the work, and after due consideration make drawings to work by. If this is not done many a ridiculous blunder will be made, and when the work is, perhaps, half completed it will be found impossible to finish it, some simple drawback having been overlooked at the outset.

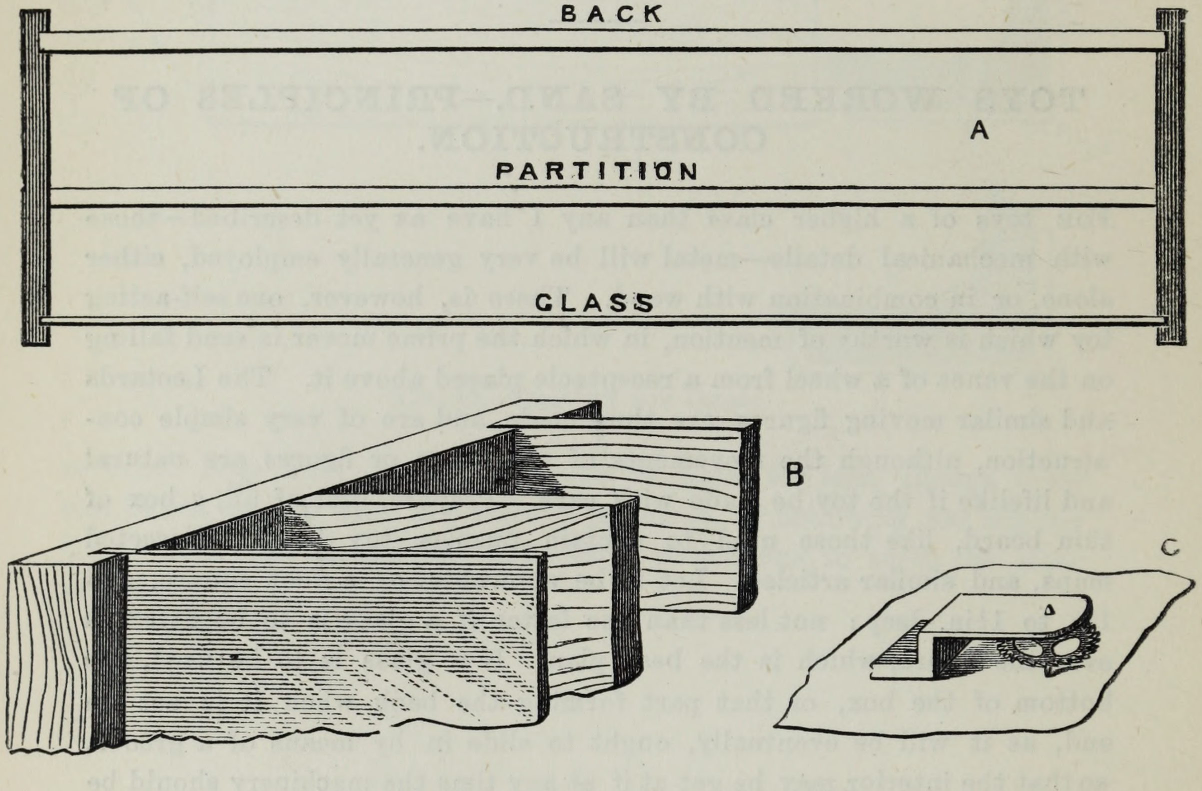


FIG. 50.—PLAN AND SECTION OF SAND TOY.

We will now return to the toy in hand. The box made as directed will have to stand on one end, and, therefore, the end in question should be made larger than a cross section of the box, so as to form a firm base. This may be moulded round its edges if it can be managed, if not,

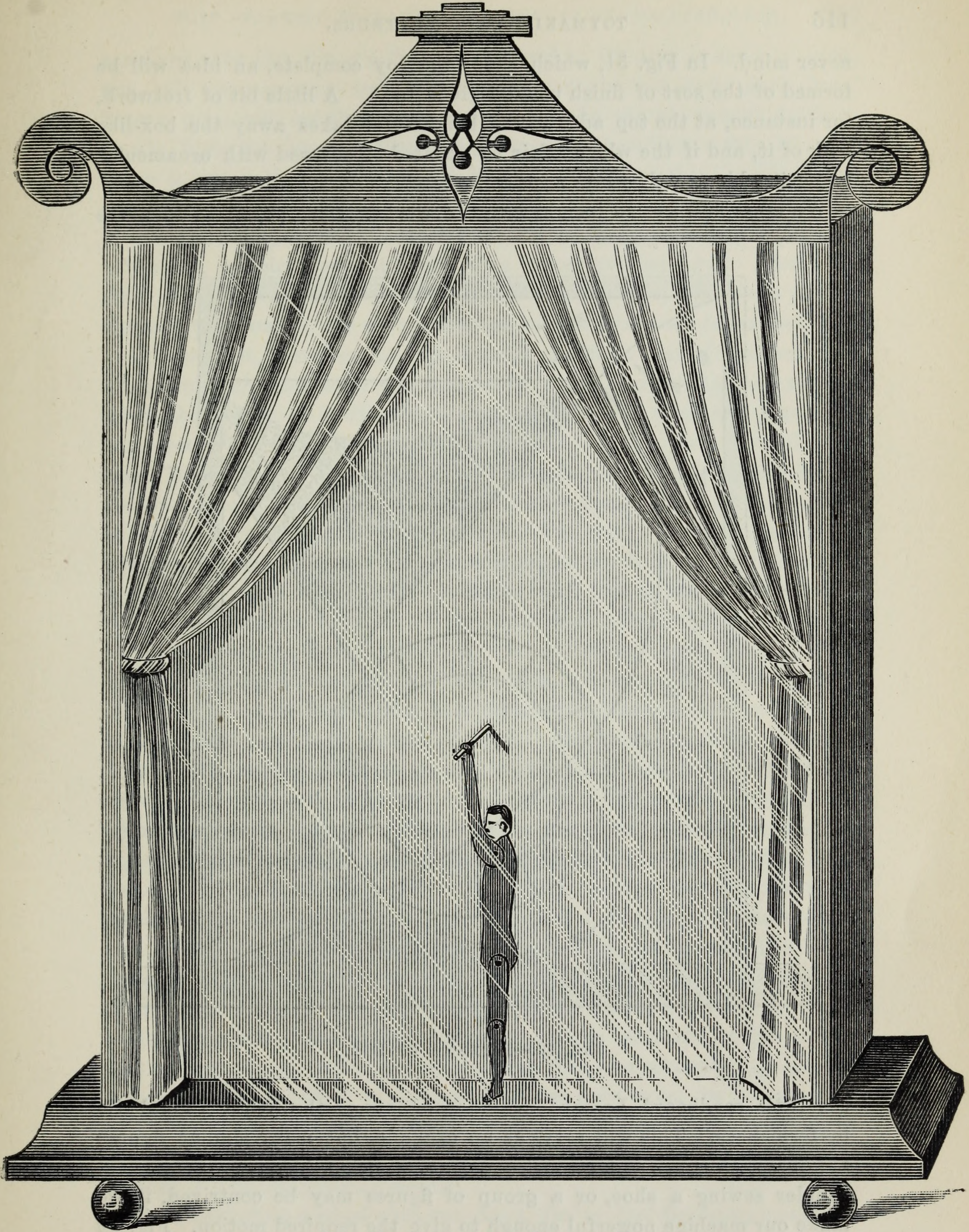


Fig. 51.—Self-acting Acrobat Toy.

never mind. In Fig. 51, which shows the toy complete, an idea will be formed of the sort of finish usually given to it. A little bit of fretwork, for instance, at the top adds to the height and takes away the box-like look of it, and if the whole affair be painted or covered with ornamental paper it adds greatly to its appearance.

We must now get an insight into the works. The object is to make the little cardboard Leotard behind the glass go through his acrobatic performances. This will serve as an example, but many similar figures are made—a smith at his anvil, a carpenter using his saw or plane, a cobbler sewing a shoe, or a group of figures may be contrived, if we make our machine powerful enough to give the required motion. Fig. 52 shows the interior of the box. It contains a wheel of stiff cardboard,

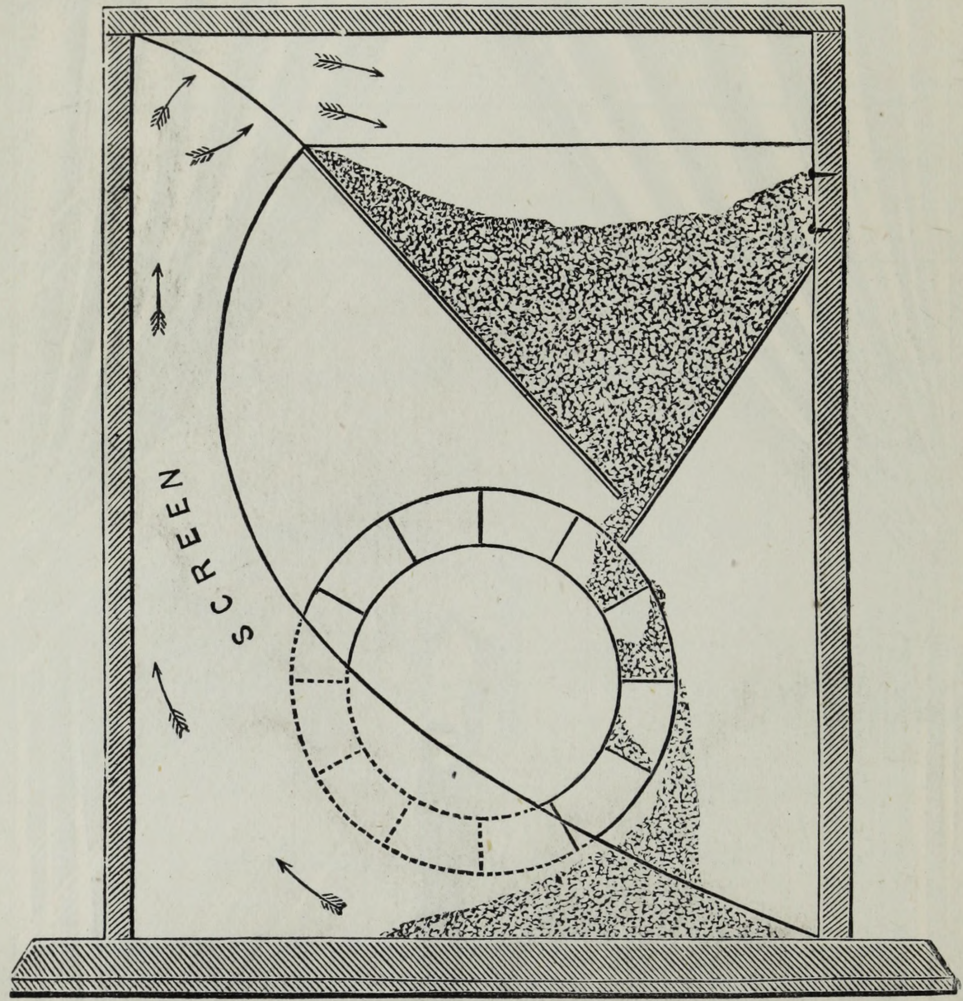


FIG. 52.—INTERIOR OF BOX.

wood, or very thin tin, as the prime mover. Card is commonly used, and will answer very well, being also easy to cut and manipulate. Strong gum will be the best cement—I mean strong enough to drop slowly from the brush; that usually sold is too thin. Buy ½lb. and make it yourself, which is a far better and much cheaper plan than purchasing it ready prepared.

The first thing to make is the wheel, similar to the driving wheel of a watermill, and the bigger it is the more power you will get. First consider what room you have for it, because on its axle, which will project through the front of the case, the arms of the figure are to be fastened. This axle must, therefore, be high enough to let the feet of Leotard clear the ground, and the lower you can put it, while bearing that necessity in mind, the better, as it will give a greater fall to the sand and leave you more room for the reservoirs containing it. If the case is made 9in. high, 7in. wide, and 2in. deep, which is ample for a single moving figure, you can have a wheel 4in. diameter, its axle being 3in. from the bottom of the case, which will do very well. You may construct all much smaller, but will have more room and easier work if made of the size suggested. The wheel may be made with two round discs inclosing the floats between them, or of one only with slits cut into the edge in which to insert the floats, but in any case the thing to aim at is a wheel that will run lightly and easily. The floats, too, may be mere flat pieces, or so made as to form what in a water-wheel are called buckets, so as to contain a certain portion of sand. Flat ones generally move the figure more quickly and with greater regularity of action, but in this case we should rather aim at irregularity, because it will give a more life-like appearance to the figure. With buckets the result usually is that the figure remains nearly, but not quite, still while the bucket is being filled, and then, when it becomes sufficiently heavy to over-balance, the wheel moves rather suddenly a little way, and thus it continues to turn with a sort of hesitating motion, which is imparted to the figure. The latter then appears as if trying unsuccessfully to turn over its bar, and then, by a sudden effort overcoming the difficulty, it makes a quick somersault, hesitating again at the next movement. A little variation in the size of the buckets again will prevent too regular and undeviating motion, which is to be avoided. In attempting this care must be taken not to add more than absolutely necessary to the stiffness of the moving parts. These should have plenty of freedom of action without undue looseness, or they will fail to work efficiently.

In constructing a wheel with two discs, 3in. or 4in. diameter, commence by striking out two circles with compasses on a piece of Bristol board, and cut them out neatly to the line, taking care also to preserve the centre marks, which is the place where the axle will come. If you get your wheel eccentric and lop-sided, it will probably refuse to rotate, and be useless. Make a small hole through the centres, and run through both a bit of wire or small knitting needle, securing the discs upon it by a dab of sealing-wax. Warm the needle for this in the flame of a candle or gas lamp so as to insure the union of the wax with the metal, and also to give time to adjust the discs nicely at a distance apart of about ¾in. (if the case is 2in. deep set them at 1in. apart). This needle will hold the discs steadily while proceeding with the buckets or floats. If they are to be flat, cut out ten for a 3in. wheel. Let each be 1in. long and a little wider than the space between the discs, so that each edge can be folded sharply in order to gum them to the discs. If ⅛in. is turned up it will do very well. Mark with compasses, before the discs are mounted, the place where each float is to come, or take a narrow strip of paper that will just go round the wheel, and double it again and again until the required number of measurements is got, or just consider the 4in. wheel to be 12in. in circumference, or the 3in. wheel 9in., and divide these to suit your convenience, for ten, twelve, or any number of floats can be used, only they must not be placed too far apart. Instead of ten put eight, at 1½in. apart, on a 3in. wheel, which will be easier. But here, again, no harm will be done by irregularity, so that you need not be absolutely correct in dividing the discs. Gum in one end, and dry it, which will take but a few seconds. Then put in the one exactly opposite to it, and next the two which will subdivide the spaces thus made. These will render the wheel stiff and strong, and enable you with greater ease to insert the others halfway between these. The floats or buckets need not be of stout card, as numbers make up strength. Card a little stiffer than the thin post cards, but less stout than the best, will do well enough for the purpose. If thicker stuff is used draw a penknife along the lines where the fold is to be made, so as partly to cut the cards at that point. It will then bend up quite sharply and make a neat joint. There should be no difficulty experienced in making such a wheel as described, and it can hardly fail to be satisfactory if the directions are followed.

A similar wheel, with only one disc, may appear easier to make, but is hardly so in reality. However, I will describe the way to do it. Cut out one disc, then, of stout card, as thick at least as a stout post card, and divide it into as many parts as you will have floats. At each of these points draw lines to the centre radial lines, and with a pair of sharp scissors cut slits on these lines all round, in which to insert the floats. You must not merely snip the card, but cut out a little piece at each slit so as exactly to admit the floats, and this will need sharp scissors and nice cutting. If the slits are the least bit too wide the floats will be too loose to be secured by gum—if too narrow, the floats will stand awry, because the edge of the disc will bend in forcing them into their places.

This work is very simple, as each float has only to be secured by strong gum, sealing-wax, or one of the cements, made of isinglass dissolved in acid. There are also liquid glue, office paste, shellac dissolved in methylated spirits, and others, all alike serviceable for such work, although probably not more so than good strong gum.

I will now describe two bucket wheels, in which instead of floats upon which a shower of sand is made to impinge, this material is made to fill in turn certain receptacles, until by their weight they overbalance the empty ones, and cause the wheel, on the rim of which they are fixed, to revolve. The form of buckets has varied extremely in the case of watermills, but the ordinary shape now used in overshot wheels is that of curved floats fitted between discs of iron. These discs, however, do not reach to the axle, as in the cardboard ones described, but form two rims only, the rest of the wheel being made up with arms or spokes. Such buckets we can readily contrive in cardboard simply by bending the floats, as shown in Fig. 53, p. 120, A, B, C, D, in which three different forms are given. But in E a very simple plan is suggested, in which common pill boxes are the buckets, which can thus be obtained ready made. They can be attached by sealing wax to a disc, or between two discs, or to the end of arms or spokes, the latter making a very light wheel. But in order to facilitate the emptying of each bucket as it gets to its lowest position, it will be as well to cut away the little boxes on one side, so as to make them slope off like E. There is plenty of choice given therefore to the machine maker, and a selection can be made of that which appears easiest.

A light tin wheel offers great facilities to one who can solder, because thin tin is as easy to cut as card, and when bent will remain so. The least touch of solder, moreover, will secure the parts of such light articles as described here.

The difference between floats and buckets, in regard to power, depends on the fact that with the former a good deal of sand is wasted, and that only the impetus of the falling column of sand is utilised. But in the case of buckets we get this impetus, and, in addition, the weight of the sand that accumulates in each. Either will work the very light cardboard figures used in these toys, so that it does not much matter which plan is adopted.

The remainder of the mechanism consists of a reservoir for the sand,

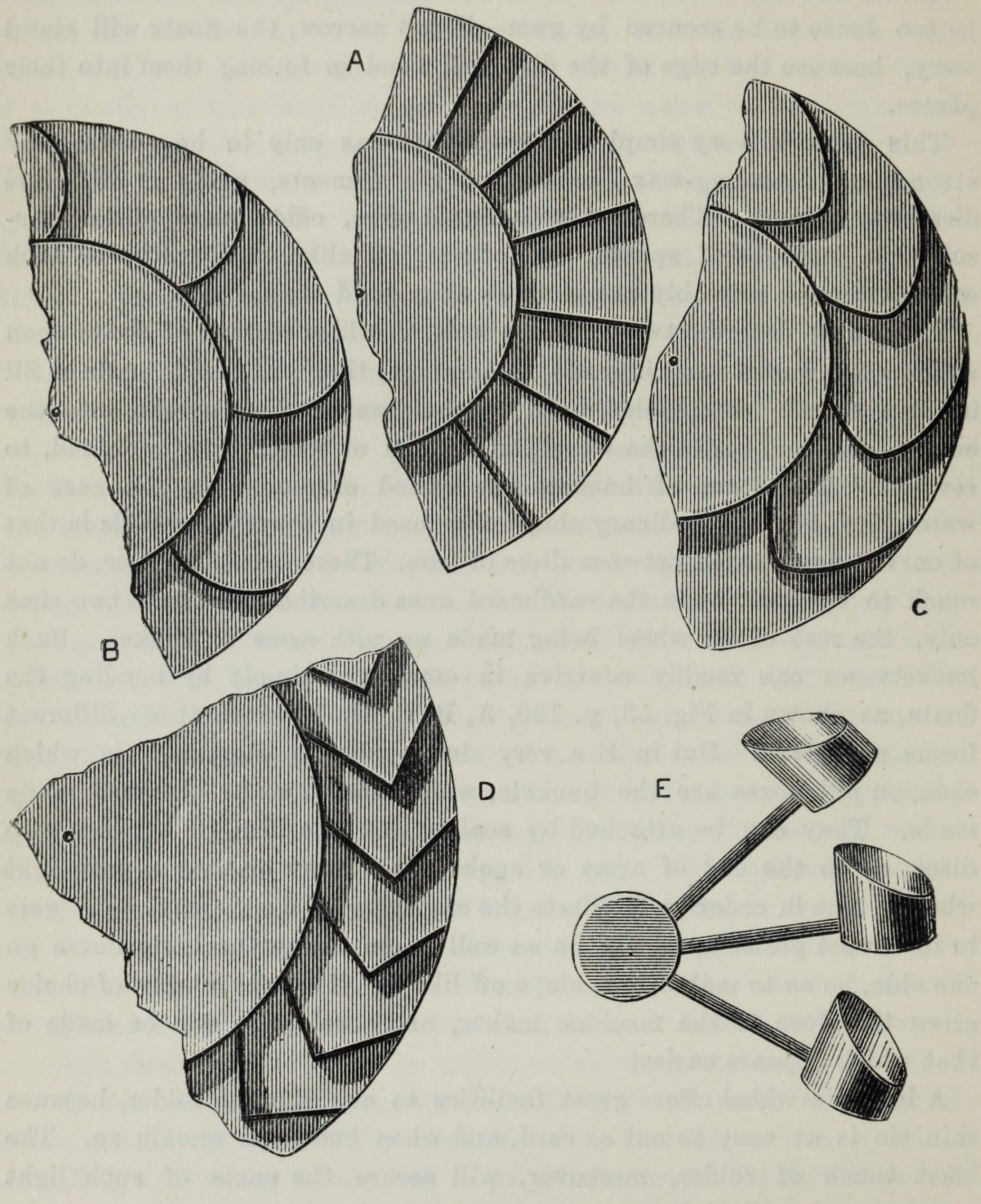


FIG. 53.—DIFFERENT FORMS OF BUCKETS.

a funnel-shaped affair, ending in a shoot which delivers the sand accurately upon the wheel, and the little athlete or other figure made with jointed limbs, whose hands are attached to the axle of the moving wheel, goes through its performance. If more than one figure is used, silken bands are passed over pulleys from the main axle to those with which the figures are connected. The latter are often replaced by mill wheels amid painted scenery, ships sailing, trains moving along a railway, and other devices.

In Fig. 52 the whole interior is seen complete. To start the movement after it has ceased, owing to the whole of the sand having run out, the box is slowly turned over, by which the sand falls against the sides of the box, and is returned to the reservoir, which should be as wide as the box is deep so as to insure its catching the whole of the sand when the box is inverted. A screen of card or tin as shown is sometimes placed to assist this, but if the reservoir fits the whole of the upper part, only a little of the sand will escape, being returned to it from the heap which it forms on the floor below the wheel. The reservoir must fit close to the box, and be glued to it as shown.

These sand toys, when neatly finished, are almost too good for a nursery; but they always afford amusement, and are capital presents to children who have passed beyond the age of systematic toy breaking. As an exercise of ingenuity in the toymaking department, they are exceedingly satisfactory objects to work upon, and give plenty of scope for cleverness in design and skill in manufacture. They also form an excellent introduction to mechanical engineering of a more important character, standing, as it were, half way between mere ordinary toys and those actuated by clockwork, steam, or electricity.

CHAPTER XIV.

CLOCKWORK TOYS.—PRINCIPLES OF CONSTRUCTION.

As all sand-power toys are of similar construction, I need not describe others of this class, but proceed to those which depend for their action upon clockwork, steam, or electricity. I may here state that clockwork toys are not as easy to make as steam-driven ones, although the contrary might have seemed probable, as for watchwork (which is the more correct term) certain appliances and a good deal of delicate manipulation are requisite to insure success. Happily, however, ready means exist for getting rid of the necessity for making the actual wheels, pinions, and springs required for toys of this description, as we can purchase them ready-made at a cheap rate. In fact, we can get what is termed a clock movement or watch movement in any stage of completion. Mr. Morris Cohen, of Kirkgate, Leeds, who has a factory in Germany or Austria, where toys are made in profusion, will, I believe, supply wheels cut or in the rough, pinions or pinion wire, clockwheels singly or in sets, ready for the aspiring amateur to fit together, and tools suitable for the work. I mention this because I was for years myself ignorant of the fact that such things could be had except by the regular makers.

The brass wheels are cast, or, for cheap clocks, stamped out. The pinions, as the small steel wheels into which the brass ones gear in watchwork are called, are made by turning away a part of a fluted rod of steel known as pinion wire, leaving sufficient of it to form the pinion required, so that the remainder, after being thus reduced in the lathe, is the arbor or axle. This wire is drawn with the requisite number of leaves, as they are termed, as five, six, eight, or other customary number, so that the teeth have not to be separately formed. This takes from the work one difficult job which the amateur must have otherwise tackled, a little light lathe work being all that is necessary so far as this portion of watchwork is concerned. Brass wheels are cut, not singly, for work of this class, but a number together, packed closely side by side on one spindle, a small circular saw traversing the lot, and thus cutting a notch on them all in succession. The spindle is then rotated by the aid of a division plate, just so far as to place the set of wheels in position for the next cut; and this action is repeated until the whole are finished. Single wheels are frequently cut in an ordinary lathe by means of one such small circular saw or cutter of the proper section; and, as the process is easy and tolerably rapid, I will describe it. There is (or ought to be) on every lathe pulley a division plate fitted with a spring stop or index, as it is called. It is used for all turned work requiring to be spaced out, whether for fluting ornamental articles, grooving taps and reamers, wheel cutting, or any similar process. In ornamental turning it is a matter of absolute necessity.

The index is a spring with a point at the upper end, which will drop into any one of the holes in the division plate, and this being affixed to (or actually itself the face of) the pulley, the latter, with the mandril and work attached to it, is fixed securely. A cut is then taken with a fly cutter (practically a saw with one tooth) or other revolving tool, driven by a band from overhead, thus forming (say) a notch between two wheel teeth. The spring is then pulled back by hand and the index point dropped into the next hole that is suitable, when the cut is repeated, and one tooth of the wheel thus formed. By a continuation of the process the whole number of cogs is completed, their exact form depending upon the shape of the spaces left between them—in other words, upon the shape of the cutter by which they have been made. Fig. 54, p. 124, will, perhaps, render the description of this work clearer to the reader. The main drawing shows all in position. M is the wheel to be cut; P, division plate on the mandril; N, the spring index; O, the revolving cutter and frame, represented larger at A, where it will be observed that the frame is a casting or forging of iron or brass, the tail, Q, fitting on the top plate of the slide rest, where it is clamped.

In this frame are two hardened steel centre screws to carry the upright spindle with its driving pulley, *a*, and saw, *c*. This saw is attached by a washer and nut as usual; *b b* are fair leaders or pulleys to carry the cord from overhead, this cord arising from the large fly wheel of the lathe. Of course, as the mandril is not to revolve, the ordinary cord is taken off and a long one substituted. I have represented the cutter frame in its profile, but in actual use it would be brought round in front, the tail facing the workman. The shape of the frame is of no importance. Anything that can be arranged to carry an upright spindle will do, and the operation is often reversed. The wheel to be cut can be held vertically, and the cutter run between the lathe centres. The present plan is generally, however, followed. Moreover, a circular cutter is not a matter of absolute necessity. D and E, for instance, fixed in a slot in the spindle, as shown at F, will answer quite as well if sufficient speed be given, and such cutters are, of course, easier to make than circular ones. They must be very gently advanced, however, and are more apt to stop suddenly and catch than saws with shallow teeth. Any bit of steel that is thick enough will make a saw for brass wheel cutting if it is drilled to fit the spindle, filed round, and then turned true on the spindle itself. The teeth, which should not be very numerous, are made with a small file, and are spaced out by the eye alone, or by help of the division plate of the lathe. But a merely flat plate so cut out will, of course, only make divisions (and thus form teeth) with straight sides, which would then have to be further shaped

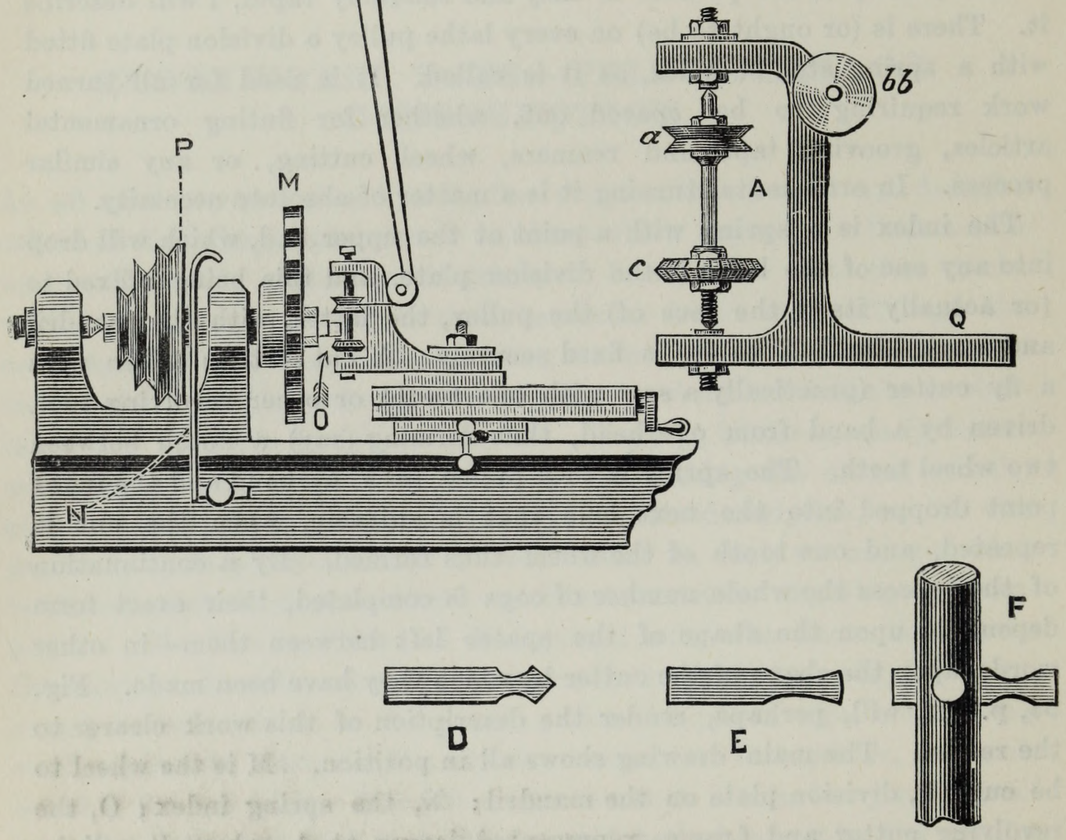


FIG. 54.—CUTTER AND CUTTER FRAME

with a file to round them off or give them the true epicycloidal form. The cutter should, therefore, be so shaped at the edge by the turning tool as to make at once the properly shaped teeth, or the latter, after having been cut with parallel sides, must be finished by a second cutter.

Clockwork for toys has, generally speaking, toothed wheels of an exceedingly rough, unfinished character, and it is put together, I suppose, so that it is certain not to last very long. But, as it generally works well for a day or two, the toy-making amateur may have a good hope that by the exercise of a little care he will succeed in making clockwork that will not absolutely refuse to go when wound up, and that with a little practice he may attain sufficient skill to make it far better than that usually sold with the cheaper class of toys. These very common watch movements, such as are embowelled in toy mice and other beasts of the kind, are not purchasable in England, literally because no Englishman would do work so paltry—it could not be sold at a price to make it pay. Probably it is done in Germany by children in their own homes, and with no proper tools or machines for wheel cutting. It is true that wooden clocks have been made with a pocket knife and file, and you may at a pinch cut teeth out very fairly in thin metal with a slitting file; but unless a lathe can be commanded, fitted as described, the better way is to spend a shilling or two in obtaining brass wheels ready made.

The actual going parts of watchwork are few and simple. Two side plates, separated by short pillars of brass, in which to place the arbors of the several wheels, is all the case required to contain the movement. The works consist of a spring coiled within a barrel, or very often wound on the arbor of the great or driving wheel without any barrel at all. A pinion driven by this first wheel, on the arbor of which is a second wheel gearing into a short endless screw upon the arbor of a fan wheel or fly, and you have all. The axle of the engine wheels or other axle to be set in motion is either that of the great wheel or first wheel of the train, or, if it requires to be driven at a high speed, it carries a pinion gearing with the great wheel.

In planning clockwork of the kind required, the relative speed of the various wheels is unimportant, and the sizes of them will depend generally upon the space at disposal. As to the number of wheels, always aim at having as few as possible, because friction is the great obstacle to be contended with, and the more working parts in a machine the more friction there must of necessity be. I have seen a drawing of a clockwork boat with just twice as many pinions and wheels as were needed—I suppose, in order to look complicated. Let simplicity of construction be the rule, and a failure will be the exception. First draw on paper or thin card with compasses what a watchmaker calls the calibre or caliber, *i.e.*, the plan of the wheels. These need not be drawn with teeth, but merely as circles, like Fig. 58. Draw these, which represent wheels and pinions, of full size, and so that they overlap as far as you think would allow the teeth to gear together. Be on your guard against searing the wheels too deeply. The watchmakers use a special gauge for testing the wheels, side by side, before drilling holes for the pivots. Thus you also find the exact places, viz., the centres of circles in which holes would be drilled for the arbors. Then take your pieces of flat brass plate intended to form the sides or case of the works, and, laying the paper upon it, prick, with a sharp punch, all the centres required. You need not do this on both plates, because you can pinch them in a vice together and drill them as one. You must at the same time also mark exactly where the little pillars will come, *a*, *b*, *c*, *d*—three or four—to keep the plates the right distance apart. If all the holes are accurately drilled it will save you an immense amount of subsequent labour and disappointment.

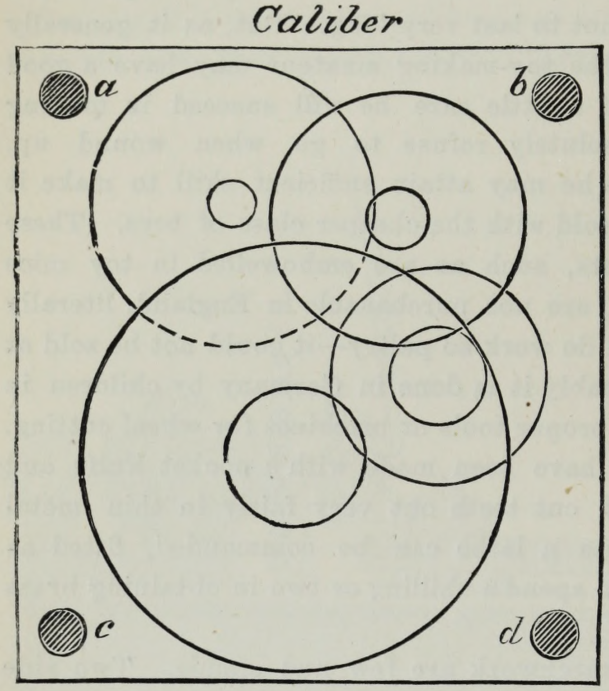


Fig. 55.—Caliber, or Plan of the Wheels.

Now fit the plates together by means of the pillars. These may be turned or filed up, which latter will do for small work of the kind suggested. Take great care to make them exactly of equal length, with shoulders square and true, and with rounded tenons to fit the holes drilled, which will of course be much larger than those for the arbors of the wheels. I may mention here the use of broaches for enlarging such holes. They are of steel wire, with generally five flats filed on them, to give cutting edges, which, blunt as they are, suffice for brass. They are called pivot broaches, and can be obtained at Cohen's for 2s. —a dozen in the set—and a handle with a clip, at 6d., to hold any size.

Here, again, is an instance of the cheapness of German tools; and having bought and used them, I can state that an amateur needs no better. Drills, again, for this work may be actually had with box and steel stock in a box, at 7s. 6d. for a set of 126, or for models, forty-eight, with drill stock, at 5s. 6d., varying from $\frac{1}{32}$in. to $\frac{1}{8}$in.

The holes, then, having been drilled and broached, and the pillars fitted, the wheels and pinions demand our attention. I have, however, presupposed the side plates of sheet brass to have been filed quite flat and true, on the inside, at least. Being, probably, no larger than those of a watch, this need not be considered a very difficult job. It should, nevertheless, be done carefully, so as to get all parts of the plates of equal thickness. The best way is to turn them upon a face plate of wood, sticking them on for the purpose with turner's cement, but filing will do almost as well for our present purpose. You can fix a bit of brass for filing upon a block of wood by means of cement, and hold the wood in a vice, or secure it by driving tacks in all round the edge, keeping their heads just below the surface. Such small plates, indeed, present no difficulty in this respect. With lathe and slide rest all is absolutely easy to a turner, who will level a pair of such plates in a few minutes. I have supposed the wheels to be purchased with teeth cut and centre hole drilled to fit on the arbor, which has now to be turned from a length of pinion wire. Now, even for this job filing may answer, but a small lathe is the proper tool to use—a watchmaker's "turn" being that used by the trade. If, however, you inspect a bit of clockwork out of an automaton mouse, you will see that the lathe is not absolutely indispensable, for a number of such arbors are made by holding a bit of wire in a hand vice or pin tongs, and rounding it at the ends by a file upon a filing block, which is a bit of boxwood held in a vice with a groove or two filed in the surface in which to lay the wire. For an arbor an inch long the best way to turn it is to grip one end in a self-centreing drill chuck, and to bring against the other, previously filed to a conical point, a hollow lathe centre in the back poppit, *i.e.*, a centre with a shallow conical hole, instead of a projecting point.

This will efficiently hold and support the work, enabling the arbor to be turned to fit the hole in the wheel in which it is to be fitted; but for the still more important part of it—the pivot—which is to turn in the brass plate, there is needed some equivalent to a pivot centre, as used in a watchmaker's turn. This little lathe it will, perhaps, be advisable at once to describe, as it will enable the matter in question to be better understood, and for very small work no tool is, perhaps, so thoroughly well suited.

The watchmaker's turnbench, or "turn," as it is usually called, consists of a flat bar of steel, to be held in the vice at one end. Upon this are fitted two small poppits, with clamping screws underneath, to fix them at any required distance apart. There is no mandril, but the upper part of each poppit is drilled through horizontally to receive what are called centres, or pivot centres—*i.e.*, plain steel bars with either points or hollow centres or flat ends. Any of these can be used and fixed by thumbscrews. If two pointed ones are used, the points will exactly meet, like the points or centres of any other lathe. It is, in fact, a lathe without a mandril and pulley, and the work is mounted between centres and carries its own pulley, which is always actuated, like a drill, with a bow. There is, of course, a small handrest, and the graver is held in the right hand, while the work is rotated to and fro by means of the bow held in the left. All the finest watchwork is turned thus.

Now, it is plain that if we take a bit of iron or steel rod, drill centres at each end, fix on a brass pulley, and drive it with a drill bow, we can turn down either or both ends to form pivots, and also true up the middle part of it as we may wish, but still we cannot finish it quite up to the centres. To provide for this the pivot centre is substituted for one of the joints of the lathe. Suppose, instead of having a point, this centre is accurately drilled with a hole just large enough to admit the pivot thus far turned, and that a flat is now filed on one side until it fairly cuts into this central hole, we shall now see the pivot revolving in it, and can hold a file down upon it so as to cut it. This is a pivot centre, enabling the whole pivot to be seen and finished first with a file, and subsequently with a bit of oilstone or with a flat steel tool with oilstone powder. These pivot centres are sold in sets of six or eight, each drilled out to a different size—some left thus, some filed out as specified, but not quite to the end, leaving a little perforated disc, which is practically like one hole of a miniature cone plate or boring collar, but each one so planned as to enable all kinds of pivots and small work to be held and turned. The verge pivot of a small watch is as fine as a hair, but it must be turned, filed and polished, to say nothing of being hardened. All this is done with perfection of skilled labour in first-class work, but in ordinary watches there is no attempt at hard pivots, and the smooth and dead smooth pivot files are alone used, all further polish being omitted. The file will quite suffice for our present purpose, and the pivot centres and turn bench can be done without if a little discretion is used; but it was necessary to describe the mode of actual work followed in order to make clear what is meant by finishing pivots in work of this kind. We evidently need what is practically a filing block only, if we hold one end of the work in a jaw chuck; or a boring collar if we centre it only and drive with a carrier; but this is not proposed, because a drill chuck is so efficient for small work of this class. When, therefore, the pivot is so far turned as only to need a little finishing and rounding off at the end, we can remove the back poppit, and let the pivot lie in a groove filed in the top of a bit of boxwood made with a tail to fit in the socket of a hand rest, thus forming a grooved filing block suited to lathe work instead of vice work. This will be ample support to such a small bit of metal, which can, in fact, be finished almost without any support at all, as the chuck will hold it quite stiffly. Still, such a filing block should certainly be made for this special purpose, and this method followed in turning all pivots of clockwork for models.

The usual method of fixing a brass wheel to its arbor is as follows: A short tube of brass is driven on the arbor first of all, and brazed or soldered to it securely. This is next turned down to fit very truly the centre hole of the wheel, a shoulder being formed on which to rest it. The tube is left to project a little only, above the surface of the wheel, which with the arbor is then removed from the lathe to a riveting stake held in the vice.

This stake is a block of steel with a central hole to receive the arbor, while the central part of the wheel rests firmly upon it. A hollow punch —*i.e.*, a punch that will, like the block, allow the pivot and arbor to pass up its centre, is now brought down upon the projecting bit of brass tube that was left for the purpose, and a few blows of a hammer turns this down to form a rivet head, pressing upon the wheel centre, thereby securing it to the arbor. An easier method that can be used, if no such stake and punch are at hand, is to fit the wheel as before, and then solder it to the bit of tube, called by watchmakers a collet. For still larger work, as in making a clock, a bit of screw can be cut on the collet or on the arbor, and a nut and washer made to secure the wheel, but riveting is the orthodox plan in such work; and in such very small articles as watch wheels it is doubtless the easiest and quickest, as well as the best. If the wheels are so ordered they can be had ready mounted, leaving only the pivots to be turned and finished to the required length, the cost is very trifling.

We may now consider that we can cut or procure any sized brass wheel, and can mount it on pinion wire turned away to form a plain spindle or arbor, except where a little bit has been purposely left to form a pinion to gear into the next brass wheel. This pinion, it is plain, can be left standing at any part of the arbor. Sometimes it is required to be close to the brass wheel, and at other times at the opposite end of the arbor, but seldom in the middle of it.

The next part to be considered is the driving power, always a coiled spring in this class of model. There are two methods in use, that used in English fusee clocks and watches, and that in Swiss, French, and common American ones, in which the fusee and chain, or cord, are omitted. In the first, which is the best, but seldom used for models, the spring is inclosed in a small brass barrel or cylinder, one end being fixed to the barrel and the other to the arbor which passes through it, but which in this case does not itself revolve. The chain, of which one end is attached to the barrel on its outside by a small hook, passes from it to the fusee, which is of a conical shape with a spiral groove cut upon it, on which the chain is coiled as the watch is wound. No toothed wheel is attached to the barrel containing the spring, but as the latter in its endeavour to uncoil causes this barrel to rotate upon (not with) its axle or arbor, it draws off the chain from the fusee, coiling it instead upon its own surface, and a wheel fixed to the latter gives motion to the train. The fusee is conical, in order to equalise the power of the coiled spring. When fully wound, it of course exercises more force, but this is expended first of all at the small end of the conical fusee, where the leverage is slight, and as the spring gets gradually weaker as it uncoils, the chain is drawn from larger and larger parts of the fusee, whereby the leverage is slowly and regularly increased. This is a very ingenious and practically perfect way of using the power of a coiled spring, which, however, in no case equals for regularity of action a weight and cord.

French and German clocks, as a rule, do not contain the conical fusee, and, consequently, their rate is not isochronous. At the same time, they may give average time correctly, — that is to say, if, when the spring is first wound, the rate is too fast, and when nearly unwound the rate is too slow, the one error may just counteract the other, so that a sufficiently correct mean time may be given for practical purposes. As might be expected, there is no fusee in clockwork toys, the driving wheel being on the arbor of the barrel containing the spring, or, at any rate, on such arbor if there is no barrel. A click wheel and ratchet always intervene between the driving wheel and its arbor when a fusee is used, the wheel being itself loose upon the arbor, but carrying on its face the click by which, therefore, the driving wheel is practically fixed, and compelled to revolve with its arbor, except during the act of winding. This is shown in A and B of Fig. 56. A spring keeps the click in the notches of its wheel. When, however, no fusee is used, this ratchet arrangement is disposed in a different manner, and is not then interposed between the barrel and driving wheel, the latter being fixed to its barrel and forming one end of it. In this case the arbor passes quite through the barrel, turning in its top and bottom plates smoothly, so that during the act of winding the barrel does not revolve; but one end of the spring being attached to it, and the other end attached to the arbor, the latter, as it is turned by the key, winds the spring tightly about it, giving it, of course, a tendency to uncoil, in which case the barrel is compelled to revolve with it. When thus made, the end of the arbor, after passing through the front or back of the clock, is squared, and carries the click wheel, while the ratchet or pawl is attached to the plate of the clock. This is illustrated at C and D of Fig. 56. In a great many toys no ratchet is used at all. The spring has its inner end fixed to a squared part of its arbor by simply pinching it tightly on with pliers (only it never *is* tight, but soon slips), while the other end is attached to some part of the case containing the wheels—generally one of the pillars—and to prevent it from uncoiling instantly, one of the outside wheels is held, or the key itself holds it, during the act of winding, by being put between the spokes. Toy engines, gigs, mice, &c., are all so made, thus doing away with the extra cost of a click wheel and ratchet.

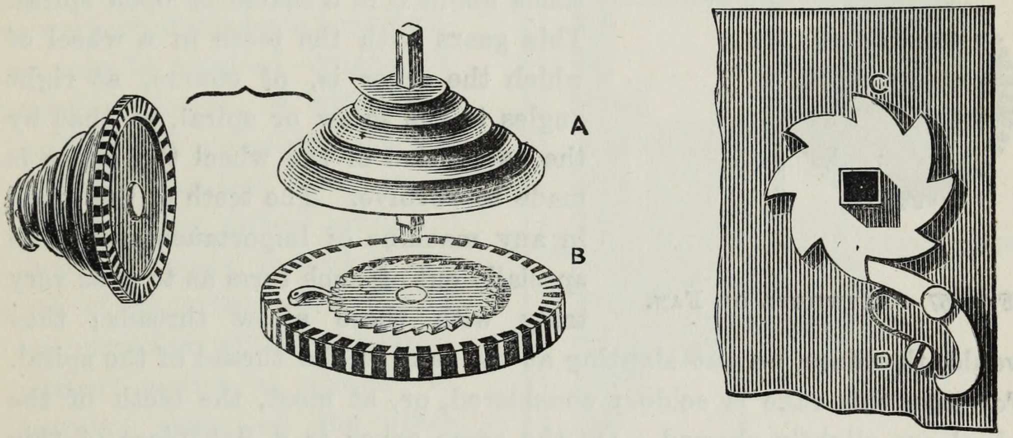


FIG. 56.—CLICK WHEEL AND RATCHET ARRANGEMENT.

We must now consider the means of regulating the pace at which the watchwork will run down after winding, and for this in all toys a fan fly is used, as also in the striking part of a clock, and likewise in musical boxes and most other machines of the kind, where it is only required to retard the rate at which the wheels would revolve without any special attention being paid to make them do so in a given period and at an unvarying speed. In the clock the pendulum or the watch escapement, called a balance, is always requisite, their movements being isochronous. The flywheel or fan is perfectly satisfactory in other cases, and this simple expedient also gives a very regular motion, though not sufficiently so for a timekeeper.

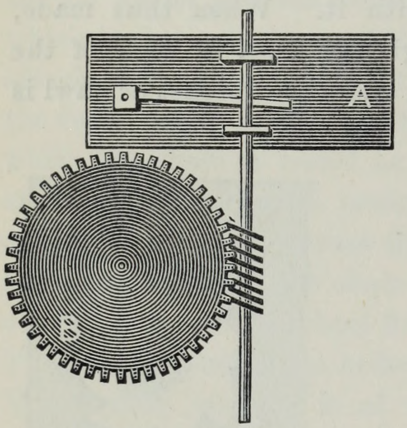


FIG. 57.—FLYWHEEL OR FAN.

The fan is made thus (see letters A and B, Fig. 57): A spindle, or arbor, as these small ones are called, has an endless screw cut upon it at some part of its length, *i.e.*, such a screw as would be formed (and is sometimes so formed) by a piece of wire coiled a few times about it in a coarse or open spiral. This gears with the teeth in a wheel of which the arbor is, of course, at right angles to the screw or spiral, so that by the revolution of the wheel the latter is made to revolve. The teeth of the wheel in any machine of importance would be specially cut of such form as to gear very truly with these screw threads; they would, therefore, be cut slanting at the rake of the thread of the spiral. For toys this rake is seldom considered, or, at most, the teeth of the wheel are slightly skewed. On the same arbor is a flat piece of thin brass forming a pair of wings which, as they revolve, are opposed by the resistance of the air, and thus retard the motion of the train of wheels. The fan is not, however, firmly fixed to its arbor, but is made with a bit of tubing soldered across its centre, which fits over the arbor somewhat loosely, but is made, by means of a flat spring, generally formed by slitting the brass, to embrace it sufficiently to revolve with it; but on the sudden stoppage of the wheel train the fan revolves a few times upon its spindle, so that all shock is completely avoided.

In such toys as clockwork carriages no fan or other regulator is required, because the friction of the moving toy upon the floor or table is a retarding force which prevents the train from running down suddenly, and not seldom proves sufficient to stop it altogether; but for working automata of a different kind from these locomotive toys it is generally advantageous to use some such regulator as the fan to equalise the motion of the clockwork, which would otherwise run down too fast. The pendulum or vibrating balance and escapement are, as a rule, not suitable, except for clock and watch movements such as can hardly be classed among toys.

Whatever the toy thus driven, the train or movement will consist of the spring, weight and cord, or other driving power, the fan with its endless screw, and one or two intermediate arbors, with their wheels and pinions, the fan or escape wheel being the quickest of the train, and the driving wheel on the barrel or fusee the slowest. To some part of this train are fitted, as may be required, cranks, or cams, or levers, by which the various motions needed are obtained, connection being made by wires or silken cords or string. Cranks, formed at the end of an arbor, revolving in one direction, will furnish intermittent motion at regular intervals; cams, on the other hand, afford means of intermittent and irregular motion depending on their shape, especially in connection with levers, which usually accompany them. By such means we can readily produce rotary motion from rectilineal and *vice versâ*, and it is hard to say what kind of movement, regular or irregular, cannot be contrived by the mechanical combinations alluded to. Modern ingenuity has brought mechanism to very great perfection, not only in the production of such apparatus as is used for weaving all kinds of

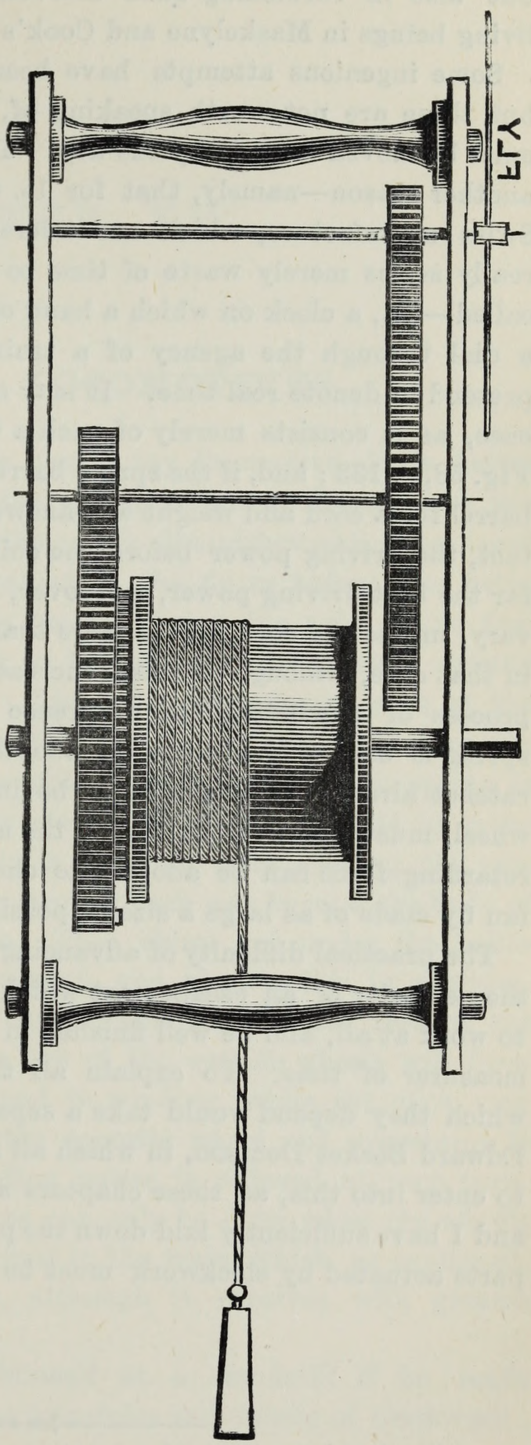


FIG. 58.—DRIVING POWER FOR TOY CLOCK

textile fabrics, or in constructing clocks almost perfect as timekeepers, but also in furnishing such marvellous automata as caricature real living beings in Maskelyne and Cook's wonderful exhibition.

Some ingenious attempts have been made to construct toy watches, but these are not worth speaking of, because in every case the hands must be moved directly by the key. Toy clocks seem equally absurd, for another reason—namely, that for 1s. 6d. or 2s. we can buy real ones of Swiss manufacture, which are tolerably good timekeepers. Hence it really seems merely waste of time to construct a toy clock, properly so called—*i.e.*, a clock on which a hand or hands shall be made to traverse a dial through the agency of a train of wheels, but which shall not pretend to denote real time. It may of course be done with comparative ease, as it consists merely of such a train of wheels as is illustrated in Fig. 58, p. 133; and, if the spring barrel should create a difficulty, a wooden barrel for a cord and weight will answer every purpose; and this was, in fact, the driving power before the coiled spring was invented. It is by far the best driving power, moreover, because it is constant, and does not vary, unless the cord makes more than one layer upon its barrel. Even in that case, although it causes increased force while the outer coils are in process of unwinding, the difference is not so great as when a coiled spring is used. If a barrel is adopted with a cord coiled upon it, the ratchet already explained must be inserted, and the driving, or great wheel, must not be a fixture in the arbor of the drum. For a toy any retarding force can be adopted to check the velocity of the train, but a fan fly made of as large a size as possible will prove most efficient.

The practical difficulty of advancing from toy clocks to real ones lies in the necessity of an escapement which must be accurately made in order to work at all, and be well finished in every detail to become an accurate measurer of time. To explain all these details and the principles on which they depend would take a separate treatise, such as that of Sir Edward Becket Denison, in which all is made clear. I have no intention to enter into this, as these chapters are specially devoted to toy making, and I have sufficiently laid down the principles on which toys with moving parts actuated by clockwork must be made.

CHAPTER XV.

CLOCKWORK LOCOMOTIVES.

In actual construction of, let us say, a toy locomotive, it is better to drive from the axle on which the spring is wound, because, as you get farther from the prime mover, the power diminishes while the speed increases. The power becomes weakest at the fly or balance, as being farthest from the driving barrel or fusee. Hence, the axle of the first or great wheel, as it is called, is to be the axle of the main driving wheels of the engine or carriage. True, it is the slowest axle of the train, but it will prove fast enough for the purpose, and carry the engine across a large room in a couple of seconds while the spring is fully wound. The best way to fix clockwork of this kind is to make it independently of the machine it is to drive, only keeping the axle of the great wheel long enough to project each way beyond the body of the toy—in this case a locomotive. Then chisel out under the boiler a recess which will hold the movement, and placing this in position, put on a covering of tin, which can be painted like the rest of the boiler. No key will be needed, as one of the outside wheels will form a much better holdfast for the hand in winding, while the click may be similarly omitted by grasping the opposite wheel and preventing it from running back when the winding power is relieved at each turn. Putting the key between the spokes can only be done when the wheels are upon the axle of the second wheel in the train, which, as explained, acts with less power as a driver, although it revolves with greater speed.

The toy maker will not find himself at a standstill if he reads carefully what is here written of the principles and details of clockwork; but it may be found that the machine stands still, owing to the too deep gearing of the wheels. In directing the formation of a calibre or pattern of the train, I have suggested the slight overlapping of the wheels to provide for the inter-locking of the teeth when the holes for the arbors are drilled by such pattern. I mentioned in reference to this that watchmakers use a special tool to ascertain exactly the distance apart of any two arbors, in order to insure the gears working freely together. This tool consists practically of a pair of watch turns hinged together side by side, and thus capable of more or less separation. One wheel is then mounted in each between centres as if they were to be turned, and are so placed as to gear together. When found to run exactly as intended, the screw which clamps the two parts of the tool at any set distance apart is tightened. The wheels are then removed and the distance taken between the centre points and transferred to the calibre, marks being made with a finely pointed dotting punch. One of these wheels is then returned to the tool and tested with the next that is to gear with it, and the same operation is repeated with the rest.

Perhaps some such plan can be managed by using the ordinary lathe centres instead of one turn, and placing either a real turn in the slide rest adjusted truly parallel to the lathe centres, or rigging up a substitute. For the latter a bit of boxwood, cut out like Fig. 59, and drilled to take bits of knitting needles to form centres, would suffice very well; and other devices will suggest themselves by casting a glance round the odds and ends of workshop appliances. Of course, if it is proposed to make more than a few clockwork models, it may be worth while to buy a secondhand pivoting tool. For small work, however, of the kind treated, if the circles of the calibre just overlap, the wheels should work together with sufficient truth for the purpose. Good watch tools are rather expensive, but they are to be readily picked up in London second-hand. Of course, wheels not mounted on their arbors can be set down flat on a piece of paper and arranged as to depth of gear, and the centres marked through the holes made for the pivots; but they are generally mounted when purchased, the pivots only of the arbors being left to be turned, and, in this case, some such method of finding the position of the pivots has to be carried out. These are matters that in all probability would not strike anyone who, for the first time, intended to try his hand at clockwork. He would count the wheel teeth, get the numbers of these and of the pinions correct,

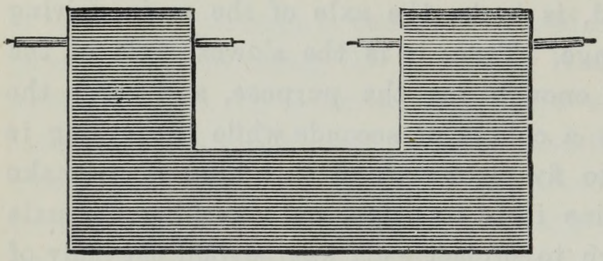


FIG. 59.—SUBSTITUTE FOR LATHE CENTRES.

and then to his surprise discover that he was in a fog about drilling the side plates for the pinions.

The greater number of clockwork toys, such as locomotive engines and carriages, are of tin, the clockwork being fixed by solder when required, but for those unacquainted or unpractised with the soldering iron, wood is the material to use. To prevent possibility of mistake I have given in Fig. 60 a side view of a wooden boiler cut away to admit the works.

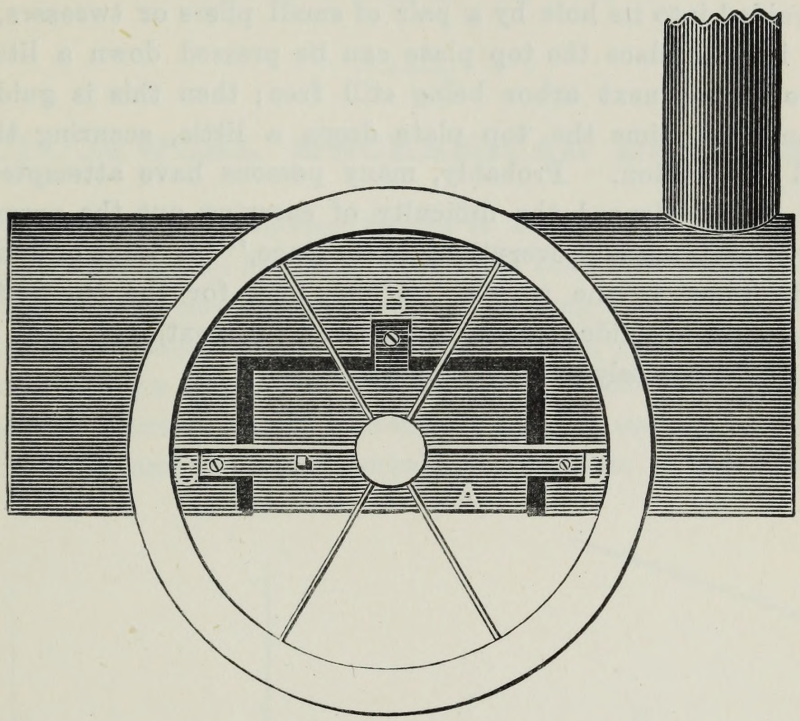


Fig. 60.—Side View of Wooden Boiler.

A is the outside near plate of the movement with lugs or projections, B C D, by which to secure it by nails or screws. There will be two driving wheels on the same axle, one, of course, being on the opposite side to that shown in the illustration. The movement would be concealed by a bit of tin plate before putting on the wheels, but is left open to show its position in the toy.

There is one apparently trivial detail of clockwork, which is, nevertheless, well worthy of attention, namely, the varying lengths of the arbors of the wheels, or rather of their pivots, which run in the side plates. Between the shoulders all are to be alike, but beyond these the pivots should range regularly. Let the great wheel have the longest, then wheel number two, generally called the centre wheel, next the third, next the fly, if this is driven with a pinion, and therefore has an arbor parallel to the others, which it may always have if preferred, but if driven by an endless screw its arbor will stand at right angles to the rest, in collets fixed to receive it, soldered or screwed to the side plates. By thus arranging the lengths of the several arbors clockwork is more easily put together. The wheels are stood up in one plate, and the other brought into place upon the pillars. The latter can be depressed to secure the axle of the great wheel, still leaving the next quite free. This is guided into its hole by a pair of small pliers or tweezers, and as soon as it is in place the top plate can be pressed down a little more to secure it, the next arbor being still free; then this is guided into place, and each time the top plate drops a little, securing that last arranged in position. Probably, many persons have attempted clock cleaning or experienced the difficulty of carrying out the proverb, "a place for everything and everything in its place," for want of knowing in what order to set in the wheels. Always look for the one that binds, and when that is guided aright search for the next, and thus proceed calmly and deliberately through the whole set.

CHAPTER XVI.

CLOCKWORK MECHANICAL DEVICES.

For any large toy with moving figures it would be as well to buy the movement complete, and then to mount upon the axles or pinions of the wheels the various cranks, cams, and connecting wires or silken cords which are to be attached to the figures. I will, however, add here a description of a few mechanical devices by which movements of various kinds can be effected. Such movements may be regular or irregular, jerky or smooth, and at varying periods or otherwise. They may also be in any required direction—vertical, horizontal, or angular. In Fig. 61 is the plain crank, either a pin on a revolving disc or a simple short arm on the end of the pinion. To this is attached a cord to (let us say) the arm of a figure carrying a sword (B), the arm being pivoted at P. The crank by its revolution will pull this string at regular intervals, and the arm will be therefore slowly and steadily raised and lowered. The motion of a crank is not quite regular, but may be considered so.

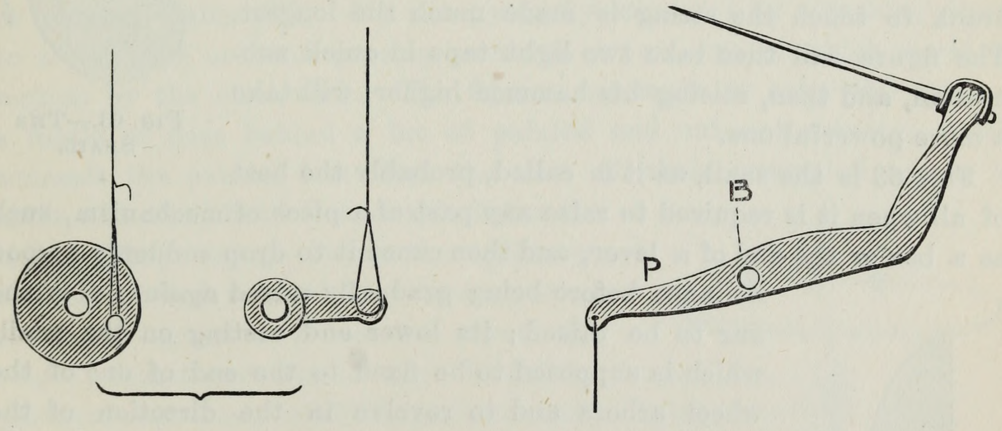


Fig. 61.—Plain Crank for Mechanical Movement Toy.

In Fig. 62 the string is fastened below to some part of the frame at A, and the crank is made simply to touch or strike it as it revolves, thus shortening it by bending it out of the straight line. There may be one, two, or three arms to such a crank, so that it may strike the string more than once during a single revolution of the arbor to which it is attached. This will raise and drop the arm of the figure suddenly, and if but one arm is given to the crank, that of the figure will remain suspended but a very short time during each revolution. It is also evident that we can put three such crank arms near together, as at C, and raise the arm of the figure three times in quick succession, causing it then to remain still during the remainder of the arbor's revolution. The hand of the figure should be weighted to make it fall sharply when released. This is a simple way of making a smith strike with his hammer on an anvil, and the effect will be greatly improved if the last arm of the crank to touch the string is made much the longest. The figure will then take two light taps in quick succession, and then, raising his hammer higher, will take a more powerful one.

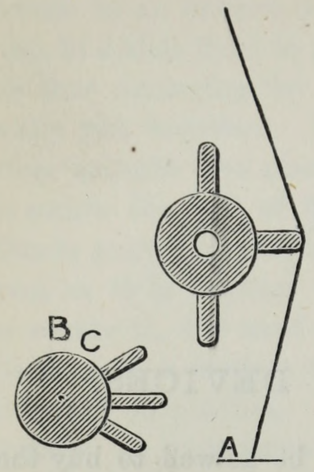


FIG. 62.—REVOLVING CRANK WITH THREE ARMS.

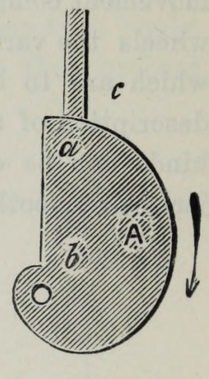


FIG. 63.—THE SNAIL.

Fig. 63 is the snail, as it is called, probably the best of all when it is required to raise any part of a piece of mechanism, such as a bar or the end of a lever, and then cause it to drop suddenly a good distance before being gradually raised again. *C* is the bar to be raised; its lower end resting on the snail, which is supposed to be fixed to the end of one of the wheel arbors and to revolve in the direction of the arrow. It will rise slowly a distance equal to the radius *A B*, and will then drop suddenly after the point *A* has been passed. This again is a perfect form of mechanism to actuate the arm of a figure intended to strike a sudden blow with a sword or hammer. The drop here is absolutely instantaneous; the curve of the outside edge of the snail is a part of a spiral, but it can be varied if irregularity is desired, and an effective variety of motion caused by making the snail with steps, like Fig. 64. The

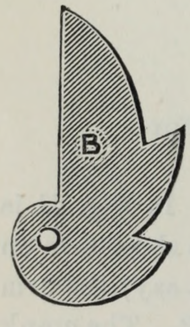


FIG. 64.—THE SNAIL WITH STEPS.

arm of a figure in this case will be raised, then dropped a little way, raised higher, and again dropped, as if taking aim, and finally raised the full height and suddenly dropped the entire distance. Irregularity of motion always adds to the naturalness of an automaton figure, because perfectly timed movements plainly indicate mechanical action. The outline, therefore, in this case should not be a perfect spiral, but, after being drawn as such, it should be made of irregular outline and the notches at unequal intervals. Processions of figures or moving trains (Fig. 65) are generally managed by attaching them to a flat tape or band passing over two drums, one of which is set in motion by the clockwork. The figures are made to enter the gate of a castle or pass behind a bit of painted and cut out scenery, which conceals the painful fact that the rest of their triumphal course is made with their head downwards below the stage. They emerge at another gateway, or from behind some similar screen, so as to appear again in procession across the stage. Sometimes one or more horizontal platforms are used, to which they are glued, and which itself forms part of the stage. This is actuated by a driving band, as shown in Fig. 66.

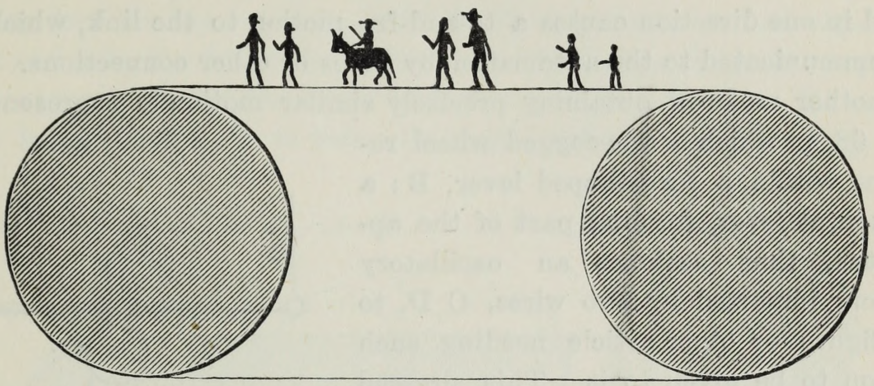


FIG. 65.—ARRANGEMENT FOR FIGURE PROCESSION.

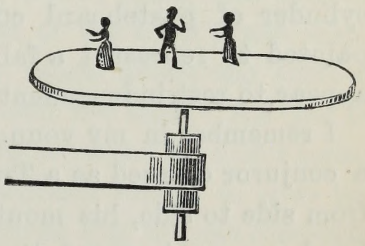


FIG. 66.—HORIZONTAL PLATFORM.

By placing such contrivance as the band, Fig. 65, vertically instead of horizontally, and so arranging the scenery as to conceal the device, figures can be made to ascend hills or ladders, or to go down into pits or mines, and various scenes of human labour may be fairly represented. Very often a reciprocating movement is needed, such as would imitate the action of a man sawing. This can be managed as before by a crank; but there are other methods which in certain cases prove to be more efficacious. Fig. 67 shows a revolving wheel of one cog, which alternately engages a pin or tooth in the elongated loop within which it revolves. This loop or link has projecting arms sliding in proper supports, and consequently the continuous rotation of the wheel in one direction causes a to-and-fro motion to the link, which can be communicated to the automaton by wires or other connections.

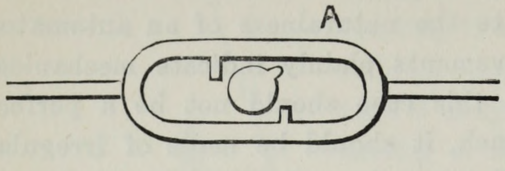


Fig. 67.—Revolving Wheel of One Cog.

Another mode of obtaining precisely similar motion is represented in Fig. 68, in which a one-cogged wheel revolves within a fork-shaped lever, B; a horizontal lever, forming part of the apparatus, thus assumes an oscillatory motion, imparted by two wires, C D, to the figure or other article needing such motion to be given to it. This, dressed up with a head, C and D forming arms, and the forked part concealed by petticoats, or a man's dress, with an apron on, will serve as a figure tolling a bell with each hand alternately. Other devices may also be so actuated, the oscillatory beam being, for instance, a seesaw, with small dolls at each end, and a hollow cylinder of pasteboard concealing the secret of its motion, might be painted to represent a fallen trunk of a tree, on which the seesaw would appear to rest independently.

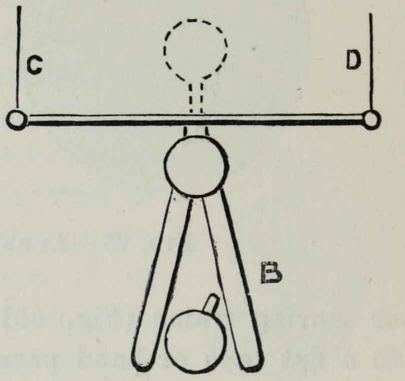


Fig 68.—Revolving One-Cog Wheel within Forked Lever, for Figure Tolling Bell.

I remember in my younger days being exceedingly desirous to possess a conjuror dressed as a Turk sitting behind his table. His head turned from side to side, his mouth opened and shut as if talking, and in each hand was an inverted tin cup. These were alternately lifted, and each time displayed something different. It was a large figure, priced at a guinea or two, if not more, and I never did attain to its possession, as my natural guardians very sensibly declined to waste so much money. But to my eyes all was mystery and wonder. The whole affair was, nevertheless, a very simply contrived toy. Two cranks connected with clock work alternately lifted the arms of the figure. By another the lower jaw (whose joint an ample beard sufficed to hide) was actuated.

The head moved by similar simple levers and strings, and the various articles to be seen under the cups were simply glued upon an endless band such as I have sketched in Fig. 65, p. 141. But there arose a necessity for keeping this band still for a few seconds just after the cups were raised. I do not remember how this was accomplished, but nothing is easier. Let there be, for instance, at one end of the driving roller a cog wheel not immediately connected with the train or movement, and let it be driven by a slowly revolving pinion of one tooth. The size of this has only to be such that it will shift the wheel which it drives a certain distance just as the cups are lowered, thus carrying out of sight one object and bringing forward another. Just as this is under the cups the single cog will have passed out of gear, at which moment the crank action is regulated so as to raise the cups, under which the article will remain quite still. Then, just before the cog comes again into action, the cups are lowered, so that the actual motion of the band is not seen. The various articles were, I think, in addition, raised above the surface of the table, in which were two round holes under the cups. All that is needed for this is a pair of revolving eccentrics attached to cog-wheels, driven, as in the previous case, by a single-toothed pinion to give an intermittent motion. This is shown in the figure at Fig. 69, one eccentric (A or B) being under each cup, and thus lifting the band, C C, each time with the article upon it, and holding it raised until the single tooth in its revolution again moves it, so that the least projecting part is upwards. The band, C C, can then move horizontally and bring the next article under the cup, at which moment the eccentric is timed to press upon the under side of the band and lift it up.

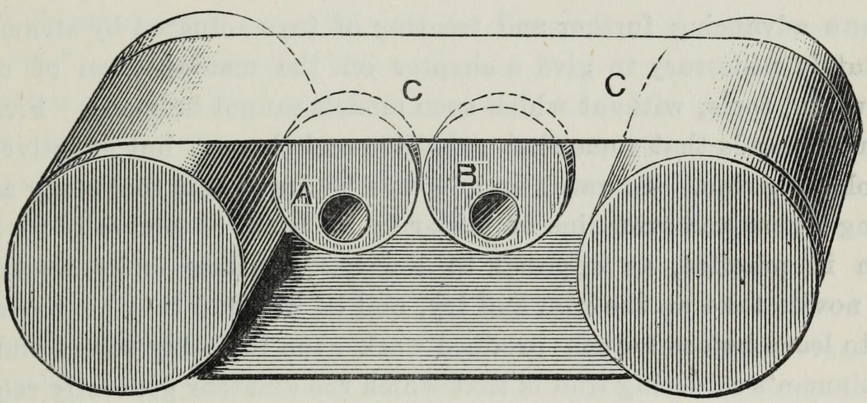


FIG. 69.—CLOCKWORK ARRANGEMENT FOR CONJURING TURK'S FIGURE.

CHAPTER XVII.

TOYS WORKED BY STEAM.—BRAZING AND SOLDERING.

Before advancing further and treating of toys actuated by steam, it is absolutely necessary to give a chapter on the manipulation of certain very useful tools, without which such models cannot be made. First and foremost stands that somewhat primitive and clumsy, but effective, tool, the soldering iron. To watch an adept as he draws this tool along a joint, leaving a neat and even line of solder in its path, is generally to gain a lesson in practice, as opposed to theory. Nothing looks easier; but let a novice take up the iron and try, and he will find that he has a good deal to learn before he can produce work even tolerably sound and neat. The tinman's soldering iron is that which the amateur generally requires, for it is a fact that plumbing is not among the trades of this many-handed individual, and I do not think I ever saw an amateur attempt it. Blacksmith, watchmaker, tinman, engine builder, carver, turner, carpenter, every trade is represented by the amateur, except that of the plumber, yet perhaps no work is more often called for. I need only remark, therefore, in this place that the plumber uses for his work in lead an iron of different shape and material, and it is used much hotter than that of a tinman. It is a solid bulk of iron at the end of an S-shaped rod forming its handle, whereas a tinman's bit is made of a piece of copper inserted in the forked end of an iron rod, which is fixed in a wooden handle, and the heat must be always below red. The shape of the copper depends on the fancy of the workman. It is generally filed to a blunt point, flattened on one side, and the copper and the iron shank are in one straight line. But others prefer to place the bit of copper at right angles to the shank, and to form it with a double bevil, making it a blunt chisel-edged tool. Much depends on the nature of the job, and it often happens that for special work the end of the soldering iron must be filed to a fresh form, not a difficult or tedious work by any means. When the copper is of the desired form, it has to be tinned, and whenever, by having been allowed to become red hot, this tinning has come off, it must at once be renewed, an untinned iron being useless, because the solder will not cling to it.

Tinning is a very simple operation of but a few minutes. The iron is first heated in a clear fire till nearly red hot, and is then screwed in the vice and filed quite bright. It must then at once be dipped in powdered resin, or for a second in Baker's Soldering Fluid, and immediately worked about in solder or rubbed about upon a bit of tin (not tinned iron), or rubbed in a shallow concavity made in a brick, in which is a drop of solder with a little resin. The copper, if not oxydised by exposure to the air in its heated state, will very quickly pick up the tin, and a bright clean layer will spread over its face. It is better to avoid its attachment on what will be the upper side, and ½in. only, or less, need be thus tinned. The soldering fluid is, on the whole, the best medium to use, but resin will answer, and has one advantage, inasmuch as it does not cool the iron. The fluid is simply muriatic acid with zinc dissolved in it till it will take up no more. Sometimes a little sal ammoniac or borax is added. For soldering zinc this fluid is absolutely necessary. Baker's preparation is sold in stone jars at 1s., containing enough to last the amateur a lifetime, as it may be diluted for general use. The object of all these appliances is to prevent oxidation of the heated surfaces, because, as soon as a film of oxide is formed, the solder will not adhere or "take," as it is called. Tallow is used on lead for a similar purpose.

Supposing the soldering iron to be thus in good order, it is heated below red, but with this limit—the hotter the better, except under circumstances which I will allude to presently, and, after being heated, it is wiped clean with an old rag, cotton waste, or a bit of tow, or, very generally, the leather apron of the workman. The edges of the proposed seam being in position, either folded or held in close contact, a line of powdered resin is dusted along it, or a small brush or bit of stick is dropped in the soldering fluid and drawn along the line, just sufficient being used to damp the surface, and the tinned iron is then touched upon the piece of solder, of which it will take up a drop. Thus charged, it is applied to the commencement of the seam, allowed to rest still for a moment so as to heat the metal well, then slowly drawn along—*slowly* mind. When the drop is used up, the iron is again applied to the strip of solder, and the operation continued. Sometimes—especially if the seam is a long one, and is not folded—the workman will hold the strip of solder in his left hand, and, applying the iron, cause a drop to fall on the work here and there to tack it together, and then, commencing as before, he will run the iron along, which will pick up the several tackings as it reaches them, and lay all down evenly as a single thin line of solder, without a break. But, in order to make a good job, the work should not rest horizontally, but inclined, so that the solder as it melts will flow onward naturally. The solder will seem to cling to the iron all the while, and will thus be led along and deposited gradually upon the work. It will be impossible to make neat work if the iron is too cold to render the solder very fluid, and the result will certainly be a thick, clumsy seam, with lumps of half-melted solder here and there ; and this will also be the case if the work is not held so as to cause the solder to flow onwards. With perfectly new clean tin soldering is a very easy matter, if these two points are kept in view ; but this is not the case with old and dirty metal, especially if rusty.

In our toymaking we are not, indeed, supposed to use dirty material, but in mending a toy we may chance to encounter such a job, and, therefore, must needs speak of it. There may often be a mere pin hole in a kettle, that anyone would think the simplest matter in the world to repair—just one drop of solder upon the hole—but a workman knows better. The solder will go anywhere else, but will obstinately refuse to lie over the hole. Soot is greasy, and specially inimical to solder, which will not take on a foul surface. But here is one of the cases in which you may often succeed with an iron much cooler than usually needed, and here, too, soldering fluid will beat resin. The surface in any case must be scraped clean all round the hole, made bright, and re-tinned by rubbing the iron well upon it with a drop of solder, and then, if a look-out is kept, it will often happen that just as the iron begins to cool, a drop of solder will draw over the hole to be mended, and complete the repair. But unless such hole is very small, the best plan is to cut a little bit of tin to fit over it, and having well tinned the vessel all round the hole, so as to get a sufficient amount of solder upon it, put a drop on the surface also of the patch; lay it on, and again apply the iron to it, so as to heat it. This will melt the solder upon its under surface, and complete the job neatly and thoroughly, far better in fact than by merely persuading a drop of solder to stick to it.

What is usually called tin, is sheet iron coated with that metal, and when solder is applied to it at a sufficient heat to melt partially the tin upon the surface, this and the solder run together and make a very sound junction. If, however, the soldering iron is not hot enough the union is far less complete, and a very little rough usage will cause the parts to separate. The process described, which is always used for tin ware, is known as soft soldering, in contradistinction to hard soldering or brazing, which is applied to iron, copper, and brass, although even with these metals the soft solder may be used wherever likely to prove sufficient.

The amateur is not very often called on to braze— an operation needing great heat and great practice—except on a very small scale ; but brass he will often find it necessary to solder, and this will not prove at all difficult. As I have stated already, soft solder is specially adapted for use on surfaces that are coated with tin, and before brass can be soldered such coating is to be applied to it. Nothing, however, is easier, unless the piece of metal is large, in which case the heat of a soldering iron is not sufficient, and the brass must itself be heated over a stove or in the fire sufficiently to cause solder to melt when applied to it. To tin brass it has to be filed clean and just damped with soldering fluid, or dusted with resin, and then a drop of solder rubbed well upon it with a soldering iron. This will very quickly coat it perfectly. When once this is done, brass can be soldered as easily as tin, and, in some respects, more so. A little bit of tinfoil placed between two such tinned pieces will unite them securely if the brass is heated till the foil melts.

Zinc is always more difficult to work, but it can be fastened with ordinary solder by using the fluid medium, the only fault of which is that it so quickly cools the iron. The usual fault is that the solder, whether for tin or other metal, is used in too great abundance. The thinner the layer, the stronger the joint, to say nothing of saving solder and making a neat joint instead of a clumsy one.

There are many cases in small work in which it is far more convenient to use a blowpipe than a soldering iron, and where such a thing as a blowpipe table with bellows can be obtained, even small brazing work may be managed, but for this, gas is almost an essential matter, with a special arrangement of burner for the production of a very high temperature. The mouth blowpipe alone is much used by gasfitters, who have acquired the necessary skill in blowing a steady stream of air, and the amateur may do this quite as well after a little practice. The flame of the candle or lamp must, however, be directed, as a rule, not upon the little bit of solder placed for the purpose, but on the metal to be soldered, until this is sufficiently heated not to chill the solder. If the latter is brought under the action of the heat first it simply melts and forms a bubble, which does not lay hold at all, or worse still, it rolls off and escapes. I mention this because I have seen the question asked.

why in blowpipe work the solder does act in the manner stated instead of running into the joint as it ought.

Copper is not very often required to be soft soldered, but when it is, it may be readily tinned by the help of sal ammoniac after having been filed bright, and then it can be soldered like the metals of which I have already treated.

The only reason why a soldering iron need be the top-heavy clumsy form usually met with is that the lump of copper is required to retain its heat sufficiently long to enable work to be executed without such constant recurrence to the fire. But for small, light metal work, a soldering iron may also be light, and filed to a much smaller point or edge, so that it can be got into corners and awkward places. In short, so long as it terminates in a bit of solid copper its shape is of no special importance, nor its size either, and the workman can plan both to suit his own convenience. A very clever plan for use where gas is procurable is to have the copper at the end of a tube in which is a jet of lighted gas playing on the end of the copper termination. The handle is hollow, and attaches by a screw to an indiarubber tube in connection with the gas supply. This allows perfect freedom in its use, and the iron is kept steadily at the heat required, a stopcock regulating at pleasure the size of the lighted jet within the tube.

There is a process called "sweating" together soldered surfaces, which makes a good strong joint, bringing the parts into close union and uniting them very perfectly. All that is really meant by the term is, that the parts to be united, having each been first coated with solder, or tinned, are to be well heated and worked together, and then allowed to remain till cold, being preferably put under pressure during the process of cooling. This is more applicable to brass than tin, which never requires to be heated otherwise than by the ordinary soldering iron. There are in the process of soldering, as in most mechanical manipulations, little dodges practised to overcome difficulties. If, for instance, in drawing along the line of solder it misses a spot here and there, as it will sometimes do, the iron must be drawn over that spot again, and very often the same break in the solder will occur again and again from some slight greasiness, oxidation, or chance dirtiness. If now the iron is drawn along as before and the solder blown upon sharply close behind the iron it is cooled before the drop has time to run back, and the seam is thus left complete and sound. This is just one of those trifling matters that hardly appear worth mentioning, yet it may save time and trouble.

Soldering ought not to be allowed to become a dirty operation, yet it is so frequently, the hands becoming foul very quickly if the soldering fluid or resin is allowed to touch them, nor is this dirt easy of removal, except by hot water with a good lump of washing soda in it. The fluid should always be applied with a small brush — a painter's flat brush or hog tool being very convenient—and the resin taken up with a slip of tin or dusted on from a box with a hole in the lid and a small tin spout soldered into it. A very little resin will suffice, and if more is used it will but melt and spread beyond the line of solder, necessitating its being scraped off, to the detriment of the job, especially if of new tin, the surface of which is brilliant, and at once shows any scrape or rub of emery paper. The neat tin work now so general, such as we see in Sardine tins, preserved milk tins, mustard and other cases, is of itself a lesson to the amateur, and shows him what is meant by a neatly soldered joint.

Of brazing or hard soldering, used on iron and steel, copper and brass, I will make a few general notes, because such work may be needed and occasionally practised, especially if the amateur has a small portable forge, which is a most serviceable addition to the appliances of the workshop, even if forging and welding are not attempted. Any handy amateur can heat his iron or steel, and bend it or flatten it out, or draw it down and point it for making drills and for other purposes, after a little practice and instruction at the hands of some friendly blacksmith; and brazing, as well as hardening and tempering tools, is an art so very handy as to be well worth a trial.

The main secret of brazing is to have the surfaces to be united clean and well fitted, and so placed and secured as not to be liable to separate or shift their position. Borax is the flux, and as this swells up on being heated until the water it contains has been driven out, it should be first heated by itself and then powdered and kept for use. The fire must be a clear one of coke or cinders, without soot and smoke, which would sully the work and prevent it from becoming coated by the solder. Of the latter, called spelter, which is simply a kind of easily fusible brass, there are several qualities. In many cases brass wire is used, especially for brazing iron, the joint being wrapped with several layers of it, which fuse and run together. Sometimes silver solder—silver and brass melted and run into strips—is used, and this is especially advisable in all fine neat work and for steel. The spelters are, however, in some samples, more fusible, to be used with brass, and in others harder, for copper or for iron, and these require great heat to fuse them.

To fasten together the pieces which are to be united by brazing without which the heat would cause the joint to open, various devices are used, according to the nature of the job. Binding with loops of iron wire is the usual method adopted when brazing thin tubes. Sometimes, however, the edges are clipped, and are made to interlap. At other times a wall of fireclay may be advantageously so built up about the joint as to keep it in place; but this is an expedient more suited to work which is brazed by a jet of gas made to play on it—a very superior method, owing to its cleanliness and the speed with which it accomplishes the fusion of the solder. Any of such plans may be adopted for brazing those toys that need to be hard soldered, which are not many. The boilers of engines ought to be so made; but for the most part they are dependent on soft solder, with perhaps a rivet here and there for additional security.

The actual operation is always the same, whatever the work may be. The parts having been scraped clean, a little borax mixed into a paste with water, is smeared upon the joint, and upon this are laid the grains of spelter, or a slip of silver solder, except in work which can be enveloped in coils of brass wire. Thus prepared, it is held in a pair of light tongs a little above the surface of the coals, and the heat gradually raised as may be needed by the steady but gentle use of the bellows. In a minute or two the borax will begin to fuse and run, and very soon the solder will also melt and flow into the joint. The work should be gently tapped, to shake it, to facilitate the flow of the metal, the fusion of which is shown by a light blue flame. The moment this appears the work must be removed, especially if of brass, or it will itself melt. When cold, the superfluous solder is cleaned off by file and emery paper.

CHAPTER XVIII.

TOYS WORKED BY STEAM.—SIMPLE STATIONARY ENGINES.

THESE are always to boys sources of great delight, because they so nearly approach to reality. An engine is something more than a toy, size alone deciding on which side of the border land we are to place it. A single inch, more or less, in the diameter of an engine cylinder may make all the difference between a toy and a useful machine. Engines, too, are essentially *modern* toys, and, like all of a scientific character, are calculated to teach the possessor many useful lessons about what are now everyday wonders, the secrets of which the present generation of boys and girls may easily fathom. Take a boy into an ordinary toy shop, and unless he be very young his interest in the treasures which are on all sides will not be by any means great; but walk him into a shop, like that of Bateman, Stevens, or Lee's, and he will find a new excitement indeed if he be a country boy. Engines stationary, engines locomotive, traction engines, marine engines, steam ships, sailing boats, lathes worked by steam that will go into a doll's house, steam hammers, tools—every scientific toy that can delight the eye and teach the mind is to be seen and bought at no high figure.

The boys of England are indeed indebted to the gentlemen I have named in a degree they are not yet old enough to understand. There are other similar shops, but these are pre-eminent, because it was here that the system originated and developed of supplying not only finished toys of this class, but all the separate parts, with necessary tools, to enable lads and men to build up engines and machines at home. We can buy any single part, or all the parts, finished, half finished, or as rough castings, to say nothing of screws, taps, and other tools and appliances to facilitate the process of construction, and that, too, as easily in the country as in London.

Many years ago to set about making a model or toy engine was a matter of anxious consideration, even for those possessed of a lathe and tools. First there was the cylinder. If it was to be cast, the pattern had to be made in wood, and few knew exactly how this should be done. To escape this task, it may have been determined to use tubing of some sort; but where was it to be obtained? and if obtained, there were the ports, and valve casing, and flanges to be attached, and every little screw and nut had to be made at home. The boiler offered still greater difficulties; and then a flywheel had to be got, and plummer blocks, and a multitude of etceteras, which ingenuity had to supply, but which generally resulted either in a very clumsy model or an utter failure.

How different is the case now! We can take up a catalogue and pick out just what we need to set us going, and of any size—from the smallest toy to the real useful engine—and making out the list, and hunting up the moderate capital required, we can have all sent down, and certain to be fit for the purpose. Moreover, we can get working drawings and directions for the construction of a satisfactory machine from these materials. It would be most unwise in the present day to try and make up a patchwork engine from odds and ends, unless, indeed, it is to be a very small and simple affair, and the materials thus chosen really suited to the work. It affords a far better lesson in engineering to buy an entire set of parts in the rough, and to shape them with lathe and file. Screws and small bolts and nuts may now also be purchased beautifully made, and of all sizes; and small screw taps in handles to match the screws are likewise sold, so that no real difficulty should occur in fitting together the several parts of these interesting toys. If, in fact, the cylinders are ready turned, the only tools absolutely necessary are a vice to screw to the table, a pair of pliers, a few small files, Archimedean drill-stock and drills, and a screw tap or two, as above mentioned, with screwdriver. If the cylinder and flywheel are not already turned the lathe must be added. I may, however, recommend one or two taper broaches to enlarge screw holes. With these few tools alone a great deal may be done. Mr. Bateman has brought out his Eclipse lathe for this special kind of work, and although I have spoken already of another by the Britannia Co., I must not omit to speak of this one at, I think, £3 or £3 10s., as it is a very neat little tool indeed.

Mr. Lee, of Victoria Yard, Broadway, Westminster, who is in a large way of business, also makes all kinds of models and scientific apparatus, and supplies them entire or in parts, finished or in the rough. Moreover, Mr. Lee claims as a speciality tenoned castings—*i.e.*, each casting that needs to be turned has a projecting tenon by which it can be gripped in a die chuck or in a wooden chuck, thus facilitating greatly the operation of turning. Mr. Lee's small table lathe, with Cyclop's foot motor, or independent treadle, seems also an excellently designed tool, and its accuracy is guaranteed. Toymakers have, therefore, plenty of choice, and an inspection of the catalogue of Mr. Lee will show what a vast amount of material and finished work is kept in stock for the accommodation of an aspiring amateur.

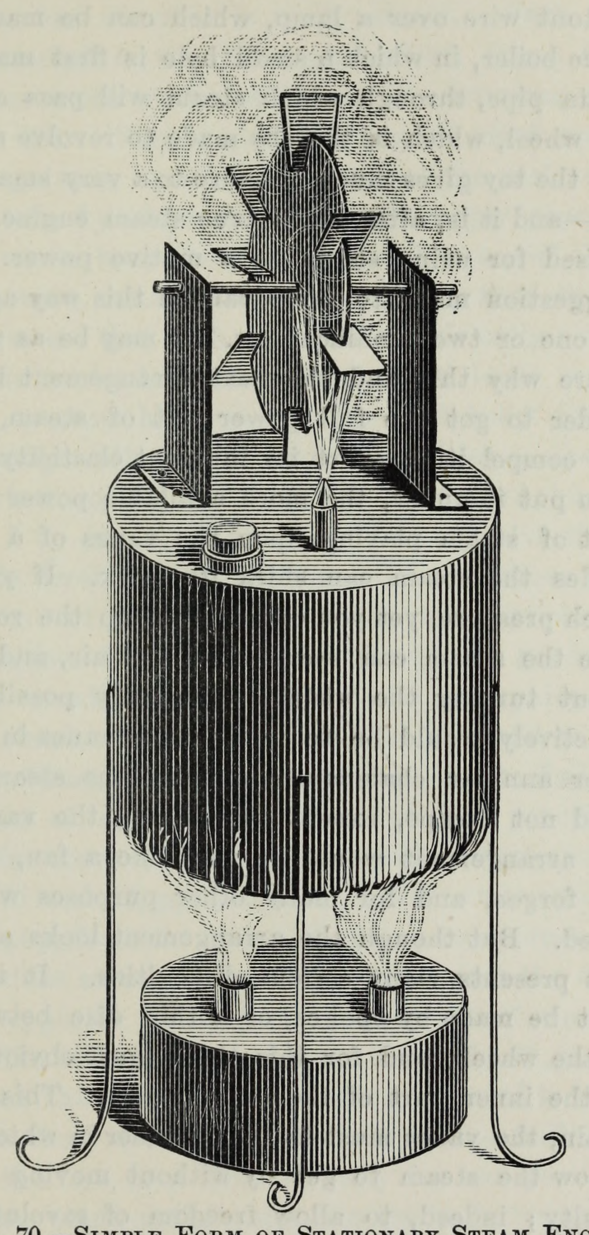


FIG. 70.—SIMPLE FORM OF STATIONARY STEAM ENGINE.

The simplest of all the engines is a toy, *par excellence* (Fig. 70), for it is nothing *but* a toy, yet it may be worth making, if only for practice in the manipulation of tools. It consists merely of a boiler, for which tin will answer quite well enough—a small empty milk tin or mustard tin, for instance—with the lid soldered on, and supported on a tripod, or on legs of stout wire over a lamp, which can be made also of tin. On the top of the boiler, in which a small hole is first made, is soldered a small short tin pipe, through which steam will pass and impinge on the vanes of a wheel, which is thereby made to revolve at a great rate. Simple as it is, the toy gives much pleasure to a very small boy—say, of 3 or 4 years old—and it is, after all, a true steam engine, made on the oldest plan devised for using steam as a motive power. I have even seen lately a suggestion made to use steam in this way again on a large scale, and with one or two modifications. It may be as well, therefore, to point out here why this and the next arrangement have been discarded. In order to get the full power out of steam, you must so confine it as to compel it to exert its inherent elasticity, and the more pressure you can put it under, the more available power will be got out of it. In a jet of steam playing upon the vanes of a wheel exposed freely on all sides the steam can shirk its work. If you have steam of 100lb. per inch pressure, yet you can easily stop the rotation of such a wheel, because the steam can escape into the air, and so expend its elasticity without turning the wheel. The only possibility of using such wheel effectively would be to inclose the vanes in some way in a circular case, or annular chamber, and drive the steam through this so that it could not escape, except by pushing the vanes out of its way. Such an arrangement would be very like a fan, as is now used in the portable forges, and for many other purposes where a current of air is required. But though the arrangement looks simple and easy to carry out, it presents many serious difficulties. It is evident that connection must be made by spokes, or a thin disc between the vanes and centre of the wheel; and for this there must obviously be an open slit all round the inner part of the annular case. This must be steam tight; and, again, the vanes must fit the chamber in which they revolve, so as not to allow the steam to get by without moving them—another practical difficulty; indeed, to allow freedom of revolution, the vanes ought not to fit the chamber; and it is here that the plan breaks down, for there is enormous waste of steam, and this cannot be avoided; and waste of steam means waste of fuel, and great cost in working for comparatively little power. Practically, the free wheel, with no case at all, is the best; because it is the most simple, and it will work, especially if the vanes are made differently, but the waste of steam is too great to bring this arrangement into use at the present price of fuel. We must, therefore, still regard this as a toy and treat it as such. It is as well here to warn the reader against the unprincipled mode often used of advertising such toys in a way that gives a false impression of what is really meant. Such an engine, with just a tap inserted in the little pipe which forms the jet, is often advertised after some such fashion as the following: "A real steam engine for 1s. 6d. This engine has a good sized metal boiler, with steam pipe, regulator, furnace, safety valve [the cork which is inserted in the short tube by which it is filled !] supply pipe, brass flywheel, &c., &c., the whole beautifully finished and japanned." The brass flywheel is, of course, meant as a lure, implying that there is a cylinder with its fittings, and that such an engine as this unique affair is not made with a cast tin or lead fly wheel, but a real brass one; and thus the reader is led to send his money in the fond belief that he will obtain *what he certainly will not.* I know how bitter is the disappointment experienced when some poor little boy has spent his small hoard in this way, and I do not hesitate to say that any advertisement purposely worded so as to deceive ought to render the advertiser liable to punishment. It is one of the cruellest of the many tricks of trade. Mr. Bateman advertises honestly and fairly, and his goods may be always trusted to be exactly in accordance with the published description. Nor does he stand alone, for in this case the misleading advertiser is the exception, although an exception far too easy to find.

The next form of steam engine, of about equal practical value to the first, and yet far more difficult to make well, is that shown in two variations in Figs. 71 and 72, pp. 156, 158. This is an engine in which the jets of steam escaping from the orifice of one or more pipes, bent in opposite directions, produce re-action by impinging against the air, and cause the rotation in an opposite direction of the reservoir of steam, to which they are attached. The little glass one represented at Fig. 71, p. 156, has, however, but one jet, and this small glass bulb is often used to send out a vapour or jet of steam from scent, which is put in the bulb instead of water, and here, by the bye, is a little mystery for our young readers. How shall we get the scent or the water into the bulb through so small a jet? Evidently it would need a fairy funnel to do it in the ordinary way. Upon the mystery centre one or two important facts immediately connected with the subject of steam engines which may at once be explained. If the bulb be warmed by the fire, or by dipping it in hot water, and the end of the little pipe is dipped into the scent, the latter will rise and flow into it as it gradually cools. After once filling the bulb no future difficulty will be experienced, for a single drop left in it will, on being warmed, become steam and expel the air, and, as this steam condenses, the scent will rise and fill it as before. Steam occupies a great deal more space than the liquid which produced it—a cubic inch of water will make a cubic foot of steam or thereabout. Heated air likewise expands and occupies more space than cold air, and is therefore, bulk for bulk, much lighter. When we warmed the glass bulb we expanded the air inside it; a great proportion of it, therefore, not finding room, escaped through the jet into the outer air. We next dipped the jet into cold scent, covering its orifice. When the air left in the bulb cooled there was not enough to fill the bulb, and a vacuum (or empty space) was created, *i.e.*, there was now less pressure upon the surface of scent inside the little tube than on that in the bottle or vessel containing it, and just as the heavy end of a pair of unequally loaded scales descends while the opposite end rises, the pressure on the scent exposed to the air (and thus more heavily weighted) drove up the lighter, and caused it to enter the globe, and it continued to do so until a balance was gained, *i.e.*, till the air inside equalled in elasticity that on the outside. If we stop up

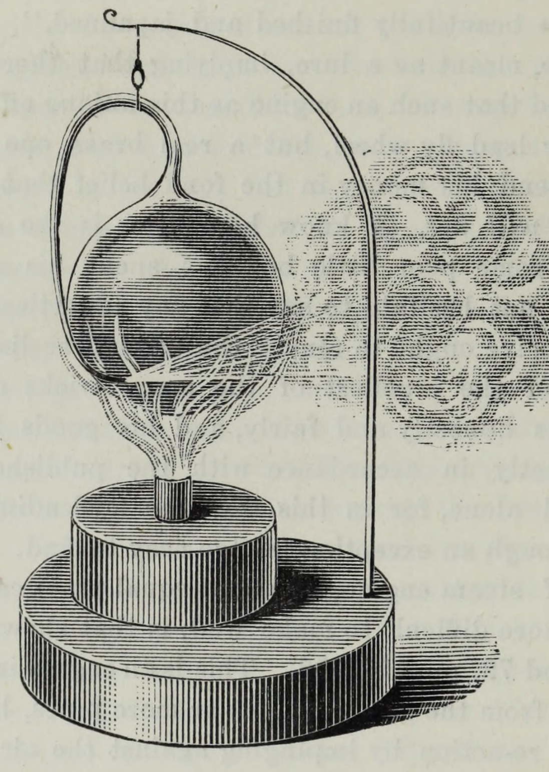


FIG. 71.—SINGLE JET ENGINE, WITH GLASS BULB.

the end of the little tube and then heat the bulb, the air inside will expand and burst it, and, if a drop of water or scent remaining in it is converted into steam, under the same conditions, the same result will follow.

Toy engines are made with boilers of tin, or brass, or copper, the latter generally brazed or riveted. If there is no safety valve these little boilers become dangerous. The pipe for the escape of steam may get stopped up, and all at once the boiler may burst without warning, and the young engineer may be seriously scalded and otherwise hurt. Hence, even for the simplest engine, provision must be made against accident. The most direct way is to close the tube by which the boiler is filled by a cork, which will blow out if the pressure becomes excessive, but I will give directions by and bye for making a proper and efficient safety valve. For the vane wheel, however, and reaction engines which is here illustrated, the cork is quite as good as anything that can be devised. It would be a waste of time to apply a regular safety valve to such a toy as this. Very often the water hole, or " man hole," as it is called, is closed by a screw cap, and no provision against accidents is made, probably because it is considered that the steam can freely escape. So it can, unless some bit of dirt in the water gets carried down into the jet, in which case an explosion is what may be confidently expected.

The glass engine, or Aeolipile, the toy maker will probably not attempt to make, although it is a simple job to one who can blow glass tolerably well. The construction of the one with a jet acting on a vane wheel will present very slight difficulty. This wheel is easiest made of a circular piece of tin about the size of a halfpenny, with slits made all round it at equal distances to receive the vanes, or rather just enough of each vane to steady it while it is being secured by a minute drop of solder; an axle of wire is soldered into it at the exact centre, and tin supports are soldered on the top of the boiler to receive the ends of this axle. The steam pipe is best made by drilling a piece of brass wire to form a tube, but a tin penholder with a small hole drilled in the rounded top, cut off to about an inch in length, will answer capitally, or a bit of thin tin can be rolled up into a conical tube, and soldered up the side. The vanes of the wheel must be arranged to come well over the jet, just clearing it as they revolve. Sometimes the steam pipe is bent so that the jet of steam is horizontal. A little tap is also inserted, which can be bought at Bateman's, where small brass tubing may be also obtained.

All this is, of course, matter for choice, but perhaps it is wiser not to expend more than is absolutely necessary upon these exceedingly simple toys, but to reserve capital for those which need skill in construction, and are altogether of a more important character. The tin reaction engine (Fig. 72) is variously constructed, but that illustrated here is a circular tin box, with bent jets attached at four equi-distant points on the rim. The jets must all point in the same direction. They may be made straight if found difficult to bend, but must be soldered on at an acute angle like the spout of a coffee pot, lying, as it were, on their sides to a great extent. To allow the box to rotate freely on the short pin A, the bottom is depressed as shown at B to form a hollow cone, and the wire spindle above, turning in a loop D of the wire C, will allow perfect freedom. F and G are the wick holders of the spirit lamp below, which forms the stand as well as furnace, and the round box has

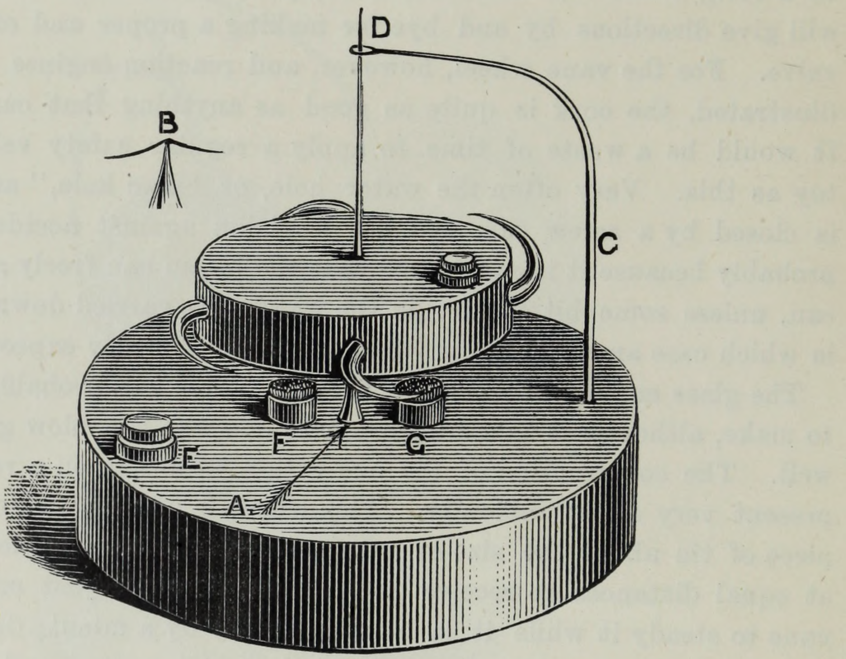


FIG. 72.—SIMPLE FORM OF RE-ACTION ENGINE.

a short tube by which to fill it, secured by a cork; a similar one at E is for the introduction of spirit to the lamp. The wick should be the soft cotton sold in balls. Here, as before, I have suggested round tin boxes, because it is easy to find such; blacking boxes, for instance, are light and suitable, and sample tea boxes (Roberts and Co., of Water-street, Liverpool, send out samples in just such light clean boxes). A larger box for the lamp, a bit of brass wire, and the materials are all found, and nothing remains but to solder neatly, and get up steam. A very small flame will keep up steam when once the water boils, and a large flare of spirits will not only not be required, but will melt the solder and loosen the jets as soon as the water is well below them. If the water be too high you will still see the rotation, but it will be caused by jets of boiling water instead of steam, making a mess, endangering the face of the engineer, and probably putting out the light. In the illustration given there are two wick tubes, but one will prove sufficient if the box be light. If there appears danger of making a hole in the bottom of the steam box in depressing its centre with a blunt punch, solder on a little lump of brass and drill it with a small hole to receive the pivot. It is not difficult, however, to make a depression in the box itself if, before the cover is put on, it is laid upside down on a block of wood with a hollow place turned in it, and gentle blows are given about the centre until the bottom takes a cupped form. Then gradually depress the centre still more, and finish with a *wooden* punch of box wood turned to a blunt core—always strike tin with wooden mallets in making apparatus, as these will not bruise it like an iron hammer. One end of the mallet should be rounded off to form a good sized convex plane, the other should be much more pointed.

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CHAPTER XIX.

TOYS WORKED BY STEAM.—STATIONARY CYLINDER ENGINES.

We now advance to cylinder engines, which are of two kinds, each more or less like those in practical use. The principle of action is simple. An accurately bored cylinder is fitted with a piston or plunger free to move up and down within it, but not so loose as to permit steam to pass around it. A rod fastened to this piston is carried through a hole in the cylinder cover by which connection is made with the crank or the axle of a heavy flywheel, either directly or through the intervention of a connecting rod hinged to it. In the first case the cylinder must be allowed to oscillate to accommodate the piston rod to the movement of the crank, this being provided for in the other case by the hinge attaching the piston rod to the connecting-rod. Steam being admitted to one side of the piston, it is thereby forced onwards until the supply is cut off, which is arranged to take place when it has reached nearly to the end of the cylinder. In a single-acting engine the momentum of the flywheel suffices to carry the piston back to its original position, when a fresh supply of steam is admitted. Each time that the piston reaches the end of its stroke an arrangement is made to allow the steam to escape, so that the descent of the piston shall not be hindered, and this only ceases when steam is about to be re-admitted from the boiler.

In the double-action engine, which is ordinarily used, steam is alternately admitted to either side of the piston, thus driving it in both directions, and doubling the power of the engine. It is probable, nevertheless, that for many purposes single-acting engines would answer very well, and they are easier and less expensive to make, if less economical to work. We will, at any rate, begin with one of these in its simplest form.

We shall require a boiler, cylinder, piston, piston rod, crank, axle, and fly wheel, also a steam block, which will be presently explained. As the boiler ought in this case to be of somewhat better construction than those previously described, attention should be paid to the following directions: It will be quite unnecessary to attempt brazing, as there is no danger whatever of ordinary solder giving way if the engine, when made, be carefully used. It is quite as unlikely to fall to pieces as a tea kettle. If we allow the water to evaporate till the vessel is empty, the solder will melt, no doubt; but there is not the least necessity for this, and with ordinary care the boiler will last as long uninjured as any other part of the engine. The materials required are a short length of brass tubing and a pair of flanged ends, which are castings, and will be supplied to fit the tube selected. The best plan is to order a set of castings and boiler materials for an engine of a certain size, usually reckoned by the diameter of the cylinder, ½in. bore or 1in. bore, or any other that may be preferred. The set will include the parts named above, but it must be also stated that they are for a single action oscillating cylinder, for a beginner should make at least two of these before attempting those of double action, or those made with a slide valve. To make these, a good deal of manipulative skill is needed, and it is always a mistake to undertake a task of the kind without some fair prospect of success. Many a learner starting with a job too difficult for him gets disgusted at his failure, and takes a dislike to such work; whereas if he had attempted less and succeeded, he would have probably advanced to work of a more important character and become proficient with his tools.

A lathe is required for engine making, as it is not worth while to buy all the parts turned, and merely to put them together. This can be done certainly, but it affords no practice in mechanical work, and is not worthy to be called toymaking. On arrival, the ends of the boiler will be just as they left the sand, quite rough on both sides of the form of A (Fig. 73, p. 162). The bit of tubing will be smooth, as it is drawn between dies in the process of making, but will need cleaning. The two ends will have been already turned true and even. The first step will, therefore, be to mount one of the cast ends in the lathe. For this a wooden chuck carefully hollowed out to take the disc of brass will be the best to use, and the disc should be mounted with the flat side (not flange) outwards, because when this face is finished the chuck can easily be turned out a little more, and will then fit the edge of the disc. This edge, moreover, will allow of being turned when the disc is held at first by its flanged part, and it must be finished at this time, because if it is not, another chuck will be requisite to receive the flange after the latter has been finished. B (Fig. 73) shows the disc in section placed in the chuck, and held by its flange for commencing to turn the outer face; B is the chuck with recess turned, C the brass, shown also at A in perspective, with the flange upwards; D shows the chuck again, hollowed out sufficiently to receive the disc when placed with the flange outwards while the latter is being turned to fit exactly the inside of the bit of tubing. It will not be necessary to turn farther than the flange, as the central part may be left rough. Supposing the brass mounted as directed, a point tool or a round end can be used to take off the rough outside.

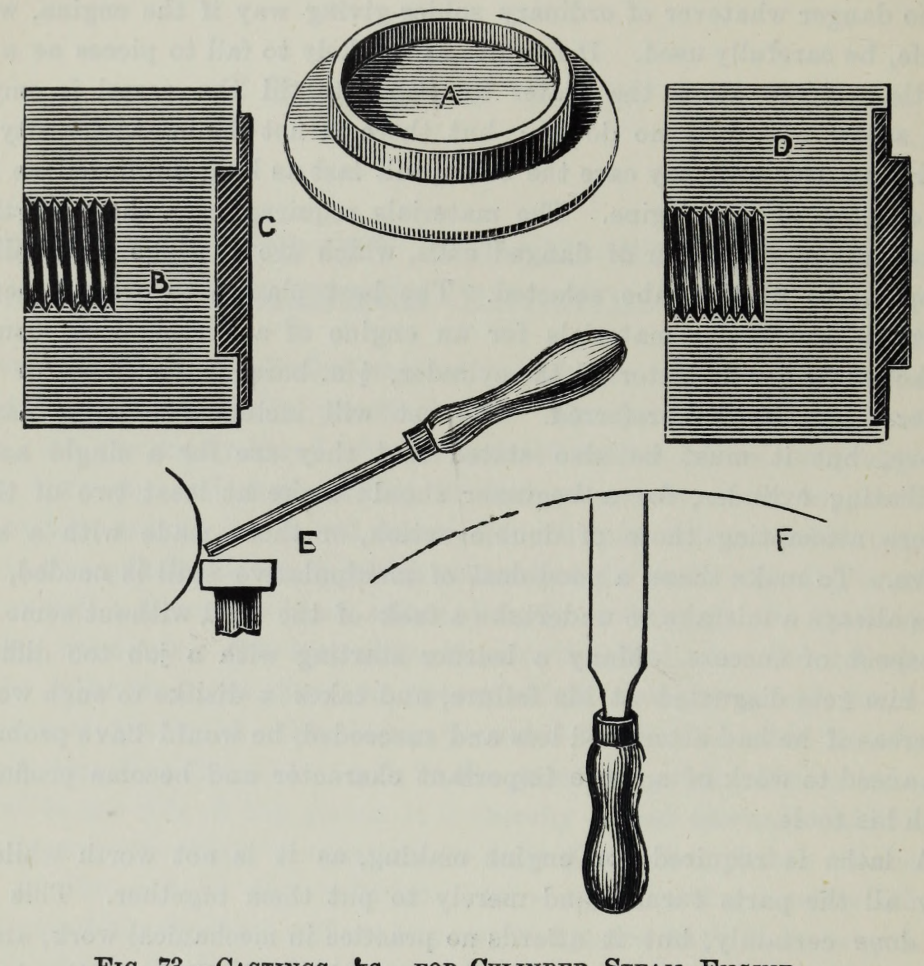


FIG. 73.—CASTINGS, &c., FOR CYLINDER STEAM ENGINE.

In the castings usually sold the surface is tolerably clean, otherwise it would need to be pickled for a short time in dilute sulphuric acid, or filed to remove the sand and grit so detrimental to tools. In any case it will be best to hold a file against the outer edge while it is in motion, to clean a place for the first action of the tool, which will thus get under the hard skin at once and cut it readily. After the whole of the outside has been turned with the roughing tool, a flat ended one is used to remove any slight ridges or inequalities. The end of this tool should not be absolutely flat, but form part of a large curve, F, and the edge should be square to the two flat sides, as it is essentially a scraping tool. It is held on the rest as shown at E. A little manipulative skill is needed to produce a good surface on brass, which is very apt, from the vibration it undergoes, to become wavy. If this once begins it is increased momentarily, and then a point tool will have to be used to cut across the ridges and produce an entirely new surface. This is peculiar to brass, and arises solely from the vibrations set up by the action of the tool. Some kinds of brass seem more liable to it than others, and it is, perhaps, best prevented by using a thin tool and a light cut, and keeping the tool in constant motion from side to side. A bit of leather or the end of the finger underneath the tool on the rest, acting as an elastic pad, will sometimes answer as a preventive, but practice enables a turner so to manipulate his tools as to check the tendency to set up these vibrations in the metal.

After using the flat tool the surface is finished with fine emery cloth, and then polished with rotten stone, whitening, and a clean, dry chamois leather. It can afterwards be further finished by a coat of lacquer. The flange is not carried to the same extent of finish, because all that is necessary is to turn it to fit, and thus also to render it clean and smooth, so that it can be tinned and soldered. The latter operation and also the finishing must, however, be postponed until one or two fittings are made, especially if the engine is to be of a complete character. In the simple oscillating cylinder and single action few boiler fittings are required. These will be detailed presently, but it will be as well to describe the mode of attaching these ends securely after they have been turned and fitted as directed. The flanged part, which will be in contact with the inside of the tube, requires to be tinned. For this purpose it should be heated till it will almost melt a bit of solder when applied to it. A soldering iron having been also heated, some solder is to be worked about all around the disc, resin or Baker's fluid being also used as a flux, until the surface is well coated with the solder. In the same way the inside of the tube is to be tinned. To unite the two it is now only necessary to heat both till the solder melts, but it is a good plan to lay the disc with its flange upwards on a close stove, such as an ironing or cooking stove, and, when the solder begins to melt, the tube already tinned is to be placed in position and pressed down close. The whole should be left a few seconds, so as to insure thorough melting and union of the soldered surfaces. If the turning has been well done, and the parts well fitted, an excellent joint will be made, and the solder will be almost or quite invisible. Both ends will, of course, be

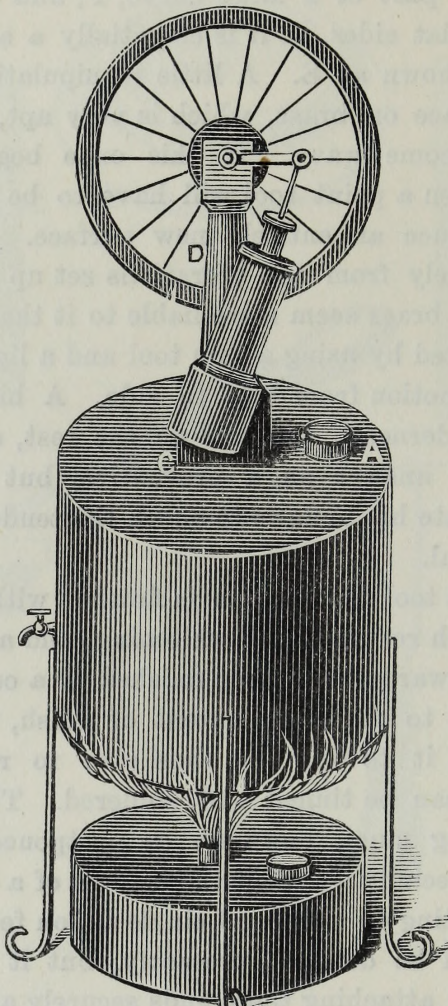


FIG. 74.—SIMPLE STATIONARY CYLINDER ENGINE.

fitted exactly alike, only that which will join the top has to be drilled with a few holes to receive the necessary fittings. These are the steam blocks against which the cylinder oscillates; the water hole with its cap, and the safety valve. In the tube itself, one or two small gauge taps should be fitted as a means of ascertaining at what height the water stands. Fig. 74 represents the complete toy, and A, C, and D the several parts to be made and fitted on the top of the boiler. The steam block is represented here as forming the base of the pillar which is used to carry the axle of the fly wheel. This will be found a convenient plan, but, if preferred, the two can be separate, the axle being supported on two standards instead of one, and in this case they can be filed out of sheet brass instead of being of the form of pillars.

We must now consider the steam block and its purpose, as upon the arrangement of this part depends the working of the engine. It consists

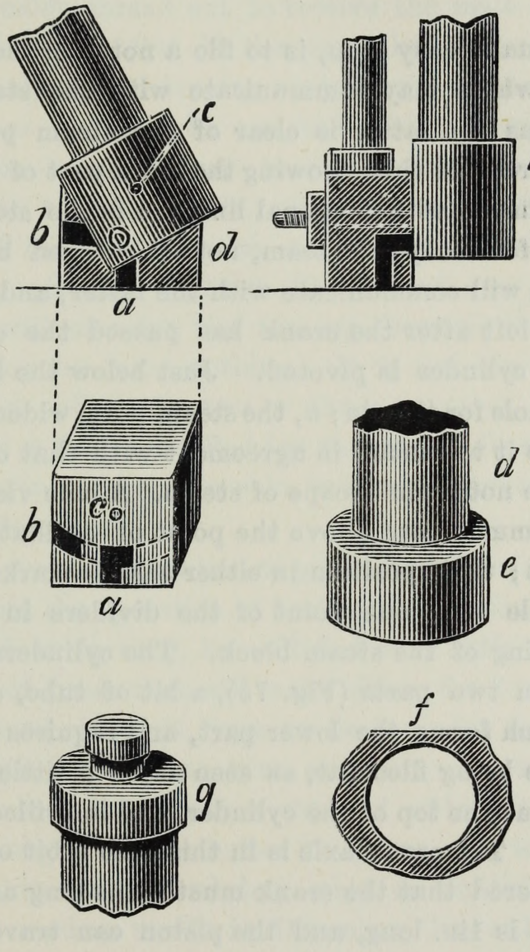


FIG. 75.—ARRANGEMENT OF STEAM BLOCK AND CYLINDER.

of a block of brass (which, as stated, may or may not form the base of a pillar) drilled to communicate with the interior of the boiler and with another hole at right angles leading into the first and terminating on the flat side of the block, against which the lower part of the cylinder is pivoted and oscillates. In this latter a hole is drilled leading into the bottom of the cylinder, which hole in one position of the cylinder tallies with that in the block, so that while the two coincide steam will pass into the cylinder below the piston. When, however, the crank causes the cylinder to oscillate, it soon assumes such a position as to shut off the entrance of steam, and this will continue until the fly wheel, by its momentum, has restored the steam ports to their first position. But in the meantime some exit has to be found for the steam as soon as it has done its work and raised the piston. In a small model, where joints are all rather slack, it generally suffices to bore a small hole near the top of the cylinder, so that as soon as the piston gets above it the steam can escape.

A better, and equally easy plan, is to file a notch or slot in the face of the steam block, which may communicate with the steam port in the cylinder, as soon as the latter is clear of the steam port in the block. Fig. 75, p. 165, represents this, showing the lower part of the cylinder and block, the latter shaded with diagonal lines; *a* is the steam port in the block, *b* the notch for escape of steam, not yet reached by the port in the cylinder, but which will communicate with the latter, and so remain when it oscillates to the left after the crank has passed the centre; *c* is the pin on which the cylinder is pivoted. Just below the block by itself is shown, with *c*, the hole for the pin; *a*, the steam port, widened a little at the top so as to enable it to remain in agreement with that of the cylinder a little longer; *b*, the notch for escape of steam. A side view is given at A. The ports may communicate above the point of oscillation, or below it, as most convenient; their position in either case is marked by describing two arcs of a circle with one point of the dividers in the pin hole, as dotted in the drawing of the steam block. The cylinders of these small engines are made in two parts (Fig. 75), a bit of tube, *d*, being screwed into a casting, which forms the lower part, and requires to be more solid to allow of the face being filed flat, as seen at *f*. A little cap, *g*, screwed or soldered on, forms the top of the cylinder, and is drilled for the passage of the piston rod. The crank axle is in this case a bit of bent wire, and it is to be remembered that the crank must be as long as half the stroke is—if the cylinder is 1in. long, and the piston can travel three-quarters of that distance, which is called its stroke, the crank must be $\frac{3}{8}$in. long at most. The pin on which the cylinder oscillates is screwed on to the flat side of it, or driven in tightly, and passes freely through the steam block. A small nut secures it, but generally it is as well to have a little coiled spring of thin brass wire under the nut to keep the faces of the cylinder and block in close contact. Here is the only difficulty in constructing such a toy. The two faces must meet, steam-tight, and yet be free to slide on each other smoothly and easily with very little friction. If the faces are not quite flat, or the centre pin not exactly at right angles to both, the engine cannot possibly work as it ought to do. The faces should be filed down carefully and finished by careful grinding, by rubbing with oil on a bit of oilstone, or on a slab of smooth iron with finest emery or oilstone powder, or with water on a slate. It is not difficult to drill truly for the central pin, and this too can be bent a little to adjust it after it is fixed in its place.

To make the cylinder very neatly and in the best manner, the thicker part, which is at the bottom, should be chucked and bored on the lathe, and an inside thread cut to receive the male screw on the other part of the cylinder. But if the toymaker is not quite up to the somewhat difficult art of tracing screws with a hand tool, he must fit the two parts as nicely as he can and solder them together, and this can be done so neatly as not to show where the joint is. All that is required is to tin both parts, place one inside the other, and heat on a stove till the solder melts, as already described in speaking of boiler making. Even a tightish fit without any solder will do well enough, as it will also for the top cap, because the pressure of steam in so small a toy is a mere nothing. It is not absolutely necessary to construct such a cylinder in two or three parts—a bit of tubing thick enough to allow a flat to be filed for the parts will answer just as well; but where made in numbers for sale, it is more economical to make them in the manner described.

It is also a very easy matter to get bits of tube quite smooth inside, and thus to avoid the operation of boring in the lathe. If the toy maker is a good hand at turning, he will find very little difficulty in hunting up a short bit of brass that will make either the lower part of a small cylinder or the whole of it, just as he can also easily make a small tube by drilling a stout brass wire, and then reducing it on the outside. A workshop is sure to contain a store of odds and ends, which can be thus used, although it is far better to go at once to Lee's, Bateman's, or some other repository, and buy what is wanted. Even if some of our toymaking readers reside in Devon or Cornwall, it is a matter of little more difficulty to have a parcel sent from London than to walk into the shop and carry off its treasure in their own pockets, and it is rare to meet with shops of the kind out of London.

The boiler described has as yet no special fittings, but these should be added, as the same boiler can be arranged to drive a better kind of engine when desired. It is, indeed, an excellent plan to make it altogether a separate affair, and lead a steam pipe from it to any engine which it is desired to try; or, if it is of tolerable size, it will drive two or more engines at the same time. You can get steam pipe of small size, and connecting joints (unions) at model makers' shops, as well as small taps, which are difficult and tedious articles to make nicely. Every boiler will be found to be the better for what is called a steam dome, *i.e.*, a reservoir upon the highest part of the boiler, into which its steam can ascend, and whence it can be conducted by the steam pipe. Where this is not done the spray from the ebullition of the water is apt to get into the pipe and cylinder, making a great mess and impairing very considerably its efficiency. This is technically called "priming," and even in railway engines is apt to occur if there is not ample steam room.

It may be stated here that most models make a mess when in action, not because they prime, which is more than probable, but because the steam, when first it is turned on into the cold cylinder and steamways, condenses into water, and this goes on till all parts of the engine have become sufficiently hot to prevent it. This occurs in large engines, and our readers have probably noticed that on starting from a station the engine driver opens two cocks in the cylinders, which, at every stroke of the piston, send out a jet of water and steam with great noise. As soon as water no longer issues, but only steam, the engine driver knows that his cylinders are hot enough to prevent condensation, and he then closes these cocks and sends the exhausted steam into the funnel, where it increases the fire draught. All this can be imitated in a model, but still there will be some mess, because the steam and water must needs blow out upon the table or floor.

Although the youthful engineer may not be altogether averse to these watery displays, an engine should have plenty of steam room, and therefore will be all the better for a dome, and it must also have gauge cocks, by which the height of water can be readily ascertained. The dome may be such literally, with a hemispherical top, or it may be a short tubular structure, with a flat top, and in either case it may be made use of as the site of the safety valve as well as the origin of the steam pipe. The readiest way is to make it of tubing, and to use a flat casting of brass for the top. This is all the more easily done, because we can get a bit of 3in. tube for the boiler with two cast ends, and on this mount on the cylindrical part a short bit of 2in. tube, 1½in. high, out of which to form the steam chest or dome. Well shaped domes can be had ready made of any size, and either of copper or of brass. Copper is the best metal to use for boilers, but it is expensive, and ought always to be brazed or riveted. No metal, perhaps, equals it in beauty when it is well polished, and it will not only stand a high pressure, but if it should burst will not fly into pieces, but tear asunder. It is very malleable, and can be readily domed up under the hammer, but it is not often used by amateurs owing to the facility offered by stout drawn tubing of brass, which, of course, needs no seam at all.

To mount a steam dome with flat top, the dome formed of tubing, the lower part must be filed out to fit accurately the cylindrical part of the boiler. This needs a good deal of care, but must on no account be slurred over. The fit must be so accurate that the least possible quantity of solder will secure the parts together. If this cannot be managed it will be far better not to add a dome, as it will be an element of danger. In any case in which such a dome is affixed by solder only let it be done by tinning the parts which are to be placed in contact, and then heating them sufficiently to melt the solder and sweat them together. The dome of copper or of brass made specially is spread out below to form a flange, which, whether riveted, brazed, or soldered, will be far more secure than the tubular shaped one merely filed out to fit, because in this case it is secured by its edge alone.

A catalogue such as that of Bateman or Lee will show how rarely a steam dome is used, except in locomotives and marine engines; but when it is omitted it will be seen that the steam pipe is first carried directly upwards for some distance before it is brought down to the cylinder of the engine. It is equivalent to a small dome, and prevents priming to a great extent. The method answers perfectly for the small models to which it is applied, and as already stated is far safer and better than a dome which may not be perfectly fitted and securely fixed. As I have known cases of forgetfulness which impaired the efficiency of a model to an extent easily understood, let me warn the toymaker who adds a dome to his boiler that he must not forget that highly necessary work of making a connection between dome and boiler by one or more holes, and the latter plan is better than a large single hole, as it is less likely to allow the water to enter the dome, which is meant specially to contain steam, and steam only.

In Fig. 76, p. 170, a flat-topped steam dome filed out and fitted is represented as carrying a lever safety-valve. This essential of a steam boiler, if safe working is to be guaranteed, consists of a short hollow plug screwed or soldered into the top of the boiler and turned truly in the hollowed part to a conical form, to carry a valve or plug by which it is closed steam tight. This plug is so placed as to be held down in its seat by a lever carrying an adjustable weight, by which the pressure upon it can be accurately regulated. The valve and its seat must be turned to a blunt cone, because otherwise it is sure to stick fast, and this may cause a dangerous explosion. I will presently show one or two different forms, because they can be made quite flat instead of bevelled so as merely to lie upon the edge of the valve seat, but this will need very accurate work to render it steam tight, and a blunt cone or even a valve of spherical or hemispherical form will not stick fast if it is kept clear. This keeping clear is, indeed, most essential to the working of all models. No parts, moreover, of small engines which are to have motion must fit tightly, friction being here a terrible enemy. Pistons must be lightly packed or left without any packing, which is the more usual plan; and all joints, such as that of connecting rods and cranks, to say nothing of brasses and bearings, must be allowed some amount of free play. The more so the smaller the model. Hence the toymaker must not be too nice about steam leakage, but be satisfied if the flywheel spins merely, or the locomotive "makes tracks" with tolerable rapidity. The lever of the safety valve may be hinged on a projecting stud on the plug joining the valve seat, or upon a separate one behind it; but the former method is the better of the two, as it saves the extra hole by which to fix such plug into the boiler, and each hole is an element of weakness. The flat bar for the lever can be made out of any suitable bit of steel, its length regulating the pressure when the weight is hung upon it. The nearer the weight is to the end of the lever, further from the hinge or fulcrum, the greater is the pressure on the valve.

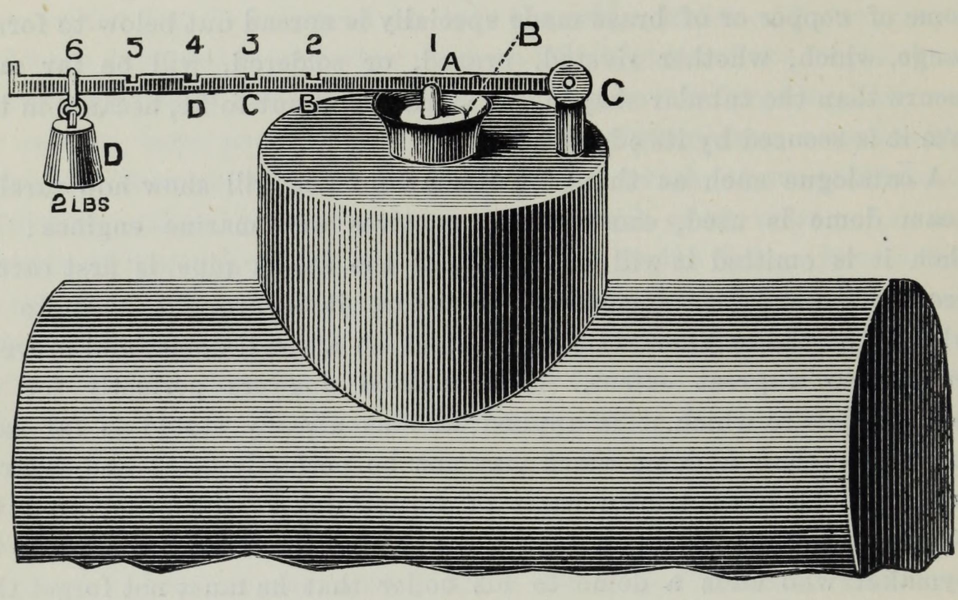


Fig. 76.—Flat Topped Steam Dome, with Lever Safety Valve.

In small models the area of the valve will probably be from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch, from which it is easy to reckon in the usual way the actual pressure per inch, this being the ordinary mode of calculation: One ounce in a valve $\frac{1}{4}$ of an inch in area will of course be equivalent to 4oz., or $\frac{1}{4}$lb. on one inch of surface of the boiler, and this again will be multiplied by the distance of the weight from the fulcrum. Practically, it is not very easy to burst a small boiler, if heated by a spirit lamp and well put together. The locomotive boilers are some of them stated in Lee's catalogue to stand safely 73lb. pressure on the square inch, and his welted iron boilers 40lb. These are for engines of some power, but the small locomotives, such as the little 10s. 6d. one, which is a marvel of cheapness, does not require that tight fitting of its parts that needs high pressure to overcome the friction caused thereby, and, instead of bursting the boiler, the steam would find its way out at various places before attaining a dangerous elasticity.

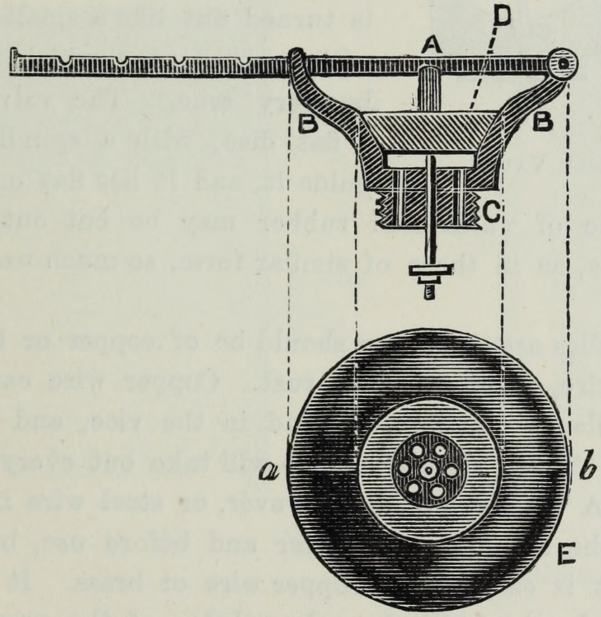


Fig. 77.—Sectional Drawing of Safety Valve.

A safety valve may be made with or without a spindle to guide it in its ascent. In a small model such spindle would be omitted. It has a certain advantage, however, irrespective of acting as a guide, inasmuch as it prevents the valve from falling off and getting lost. In the illustrations, Fig. 77 (A) is a sectional drawing of a safety valve, Fig. 76 showing the perspective view of it with the plug and lever. A bit of brass is turned to a neat cup form (B), and the bottom, which is flat, is then drilled with a few holes for the escape of steam, and with a central hole for the spindle. The valve (D) is turned conical, to fit the inside of the cup, and this has a saw cut, *a b*, made straight across it, in which the lever is to lie, and in which one of its ends is pivoted. The lower part of the cup is tenoned and cut with a thread (C) to screw into the boiler, or it may be soldered instead. If screwed it should have a lead washer to insure its being steam tight. E shows this cupped part looking into it from above.

Fig. 76 shows another neat form. Here the brass is turned flat on the top with a milled edge, and a conical valve seat is made. The lever is pivoted in a short turned pillar screwed into the flat top of the piece. Fig. 78 is another pattern. In this case the brass is turned out like a small box, with a sharp edge, which must be very true. The valve is a flat disc, with a spindle to guide it, and it lies flat on the edge of its seat; a disc of vulcanised rubber may be cut out and attached under this valve, as in those of similar form, so much used in water cisterns.

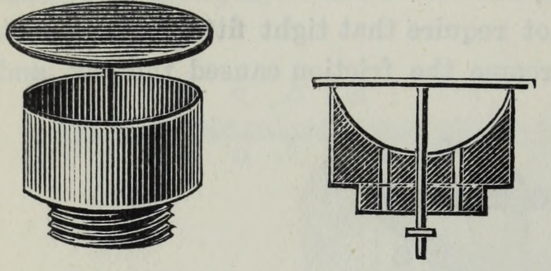
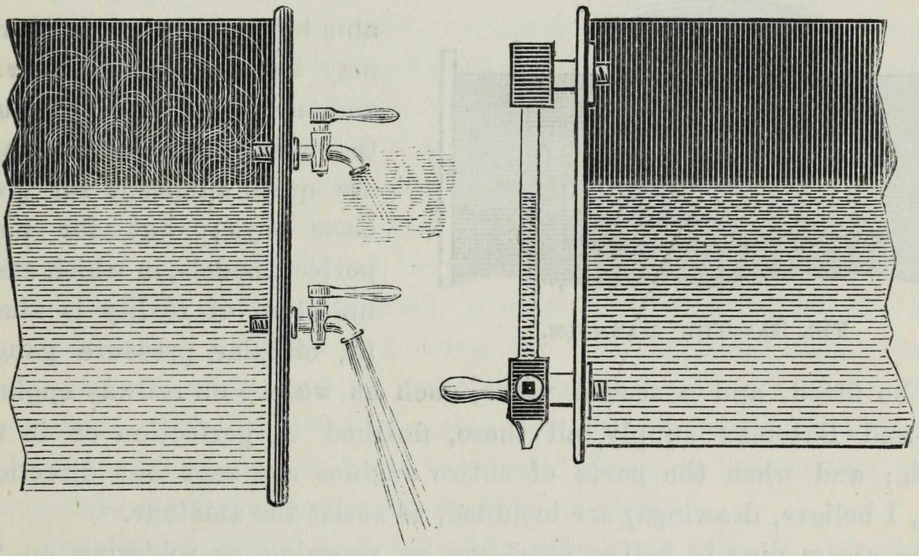


Fig. 78.—Form of Safety Valve.

In all cases where spindles are used they should be of copper or brass wire, preferably copper wire, which will not rust. Copper wire can be made straight as a needle by putting one end in the vice, and then pulling till it is felt to stretch slightly. This will take out every sign of coil or irregularity. A needle will do, however, or steel wire if the valve is lifted out and the spindle wiped after and before use, but it may give trouble, and it is easy to get copper wire or brass. It may be as well to state, in order to facilitate a knowledge of the pressure actually tending to burst a boiler, that in the case of a lever safety valve the pressure equals the weight suspended multiplied by its distance from the fulcrum. If Fig. 76 represents such a lever with weight of 2lb., C, the fulcrum, and A, the position of the valve, the distance of the latter from the fulcrum originating the scale of distances on the lever, the pressure will be 2lb. with the weight at 4lb. at B, 6lb. at C, and 8lb. at D. If the valve is of an inch area, these numbers would represent the pressure in pounds per inch. If, as suggested, the valve is $\frac{1}{4}$in. area, these pressures, multiplied by four, will give the pressure per inch. It is not very likely in practice that a 2lb. or 1lb. weight would be used on so small a boiler.

It is more likely to be an ounce, or even much less, and the pressure can only then be made great by increasing the length of lever and diminishing the distance of the fulcrum from the valve. By using a spring instead of a weight much greater pressure can be brought to bear, as a very small coiled spring may be made of steel wire sufficiently stout to be very stiff. Safety (spring or lever) valves are advertised complete in the catalogues from 1s. each, the lever pattern being rather more expensive than the other.

The next bit of fitting to be considered is the gauge, Fig. 79, which may be made with glass tube, fitted into a brass socket at each end, or may consist of two or three separate small cocks, placed one above the other. The latter are the most used as being simpler, and the glass gauges should certainly be bought ready made as well as the cocks, and then they can be fitted at home. The upper end of the glass communicates with the steam, the lower with the water space, and thus forming part of the boiler, enables the height of the water to be always clearly seen just as if the boiler itself were transparent. Of the gauge cocks the lower one should always give water, the upper one steam, and if this does not happen it shows that there is too much or too little water in the boiler. A third tap is sometimes placed intermediate between the top and bottom ones, as a still further guide to the engineer in ascertaining the condition of the inside of the boiler. These gauge cocks are made to screw into tapped holes, or made with a nut, and washer



— The Gauge.

of lead or copper. If made in the latter way they must be secured before the ends of the boiler are soldered in. In placing them allow one-third the space in the boiler to the steam, and place the lowest tap at $\frac{1}{4}$in. diameter from the bottom, and when this gives steam instead of water, fill up at once till water just begins to run from the upper tap placed at $\frac{1}{3}$in. from the top of the boiler. You will thus save the destruction of the boiler, which so often results from allowing all the water to boil away.

The manhole, which is used as the water filler, consists of a ring of brass (Fig. 80) with screw cut inside for a screw plug, or outside for a screwed cap, and can be made to solder or screw into the top of the boiler. The casting can be obtained, or any suitable bit of tube or solid rod may be pressed into service and turned to fit. These are the usual boiler fittings, and are quite sufficient for good class toys; but for more perfect models, in which exact imitation of reality is aimed at, circular pressure gauges may be fitted, and a second valve, such as we see on railway engines. Lee and Bateman supply all these, finished to perfection or in the rough; and when the parts of entire engines are sent out directions (and, I believe, drawings) are included, to assist the amateur.

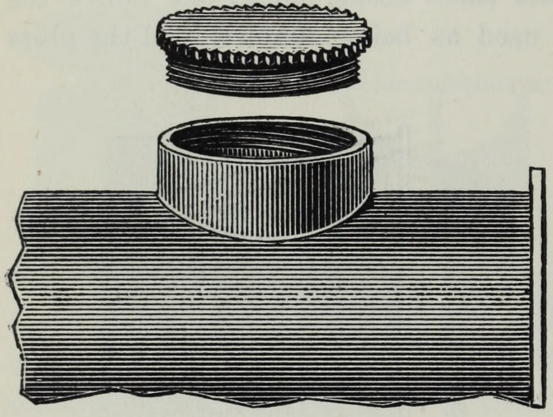


FIG. 80.—THE MANHOLE.

The steam pipe is better fitted up by screwing or soldering on the steam dome or top of the boiler; a short tube and screwed socket, called a union, by which the additional length of tubing leading to the engine can be connected at pleasure. This renders the boiler independent of any particular engine. Steam tube of brass, from $\frac{1}{8}$in. bore, is sold in lengths of 1ft., and can be cut as required, and bent in any direction. This bending requires great care, as any sudden sharp bend must be carefully avoided. Tubes large enough may be filled with sand, powdered rosin, or (if brazed) melted lead, or fusible metal, and then bent, after which the substance used is poured out. But the very small tube must be manipulated carefully by hand and gentle taps of a small mallet while laid on a convex surface. If the curve required is gradual, a bit of wire may be threaded through the tube while it is straight, and subsequently withdrawn; but gentle manipulation will generally suffice with tubes of so small size, the great thing to avoid being flattening of any part of the tube, for if this happens it will bend sharply, and thus become reduced in size or absolutely stopped up—a serious matter when intended as a steam pipe.

We may elaborate engines and boilers to any extent, but the more perfect ones, with every detail of large engines reproduced in miniature, are not contemplated in this series, it being devoted to toys and not to models, which are valued at perhaps £10 to £50, and are made at considerably higher prices even than these. The only addition, therefore, to a boiler that need be alluded to is that of a single central flue or tube, which, by conducting the heat right through the middle of the boiler renders the generation of steam more rapid. Fig. 81 (p. 176) represents such a boiler, an upright one, cut away to show the external tube. A and B are the two cast flanges forming the end of the actual boiler. This may stand on legs, or may be advantageously made as a cylindrical tube, with air holes punched round near the bottom to admit air in sufficient quantity to supply the lamp, the frame of which passes up the central tube, and may be of good size. This tube is better made conical, but if such cannot be purchased, a straight bit of brass tube will do well enough soldered into the top and bottom plates. But these must be carefully bored in the lathe to fit very accurately the tube—a good tight fit, and, indeed, if capable of such a job, the toymaker may chase a thread and screw the two together, simply using a little red or white lead to make the joint steam and water tight if necessary. The best sort of tube, however, is cast with a flange, like that shown, to enable it to be riveted down on the bottom plate when in close approximation to the flame of the lamp.

Another very good plan to avoid solder is to use a tube, D, cut with a screw thread at each end. The tube is passed quite through the boiler ends, and a washer of copper being slipped on, a hollow nut, E, is screwed up outside. Such a tube acts as a brace or stay to a boiler, holding its ends together. Now it may be stated that this is not the way the tubes are fitted in locomotive boilers; but the real plan of action there adopted would be less easy to manage successfully in a model. The method is as follows: I is a section of the thick plate forming the end of the boiler; F and G are sections of tubes. These being fitted, they are secured by driving in short conical ferules, as shown at K in section, and also in the drawing of the plate I and tubes. The tubes of copper are thus very securely fixed, and very quickly too, and the result is a neat and durable job, steam and water tight to any pressure likely to be brought to bear upon them. In our model boiler the funnel or visible chimney is to be fitted over the slightly projecting end of the fire tube C in the central figure. A boiler arranged thus will make steam far more rapidly than it will without this inside tube. A number of tubes would be of little use over a lamp, but are of great value when the furnace consists of a fire box arranged to burn charcoal, as is usual in the case of large model engines.

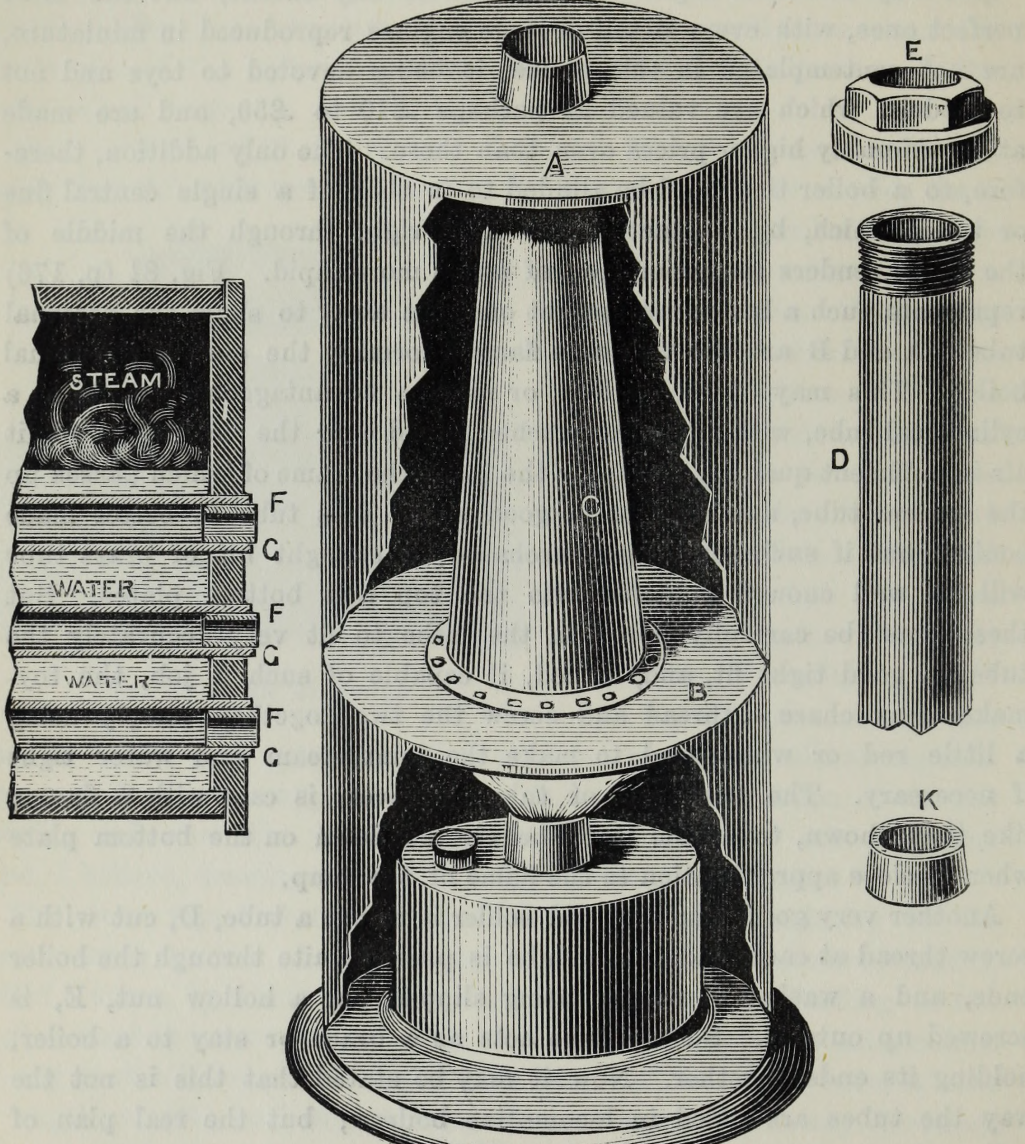


FIG. 81.—UPRIGHT BOILER WITH SINGLE CENTRAL FLUE.

In any riveting use copper rivets. They can be bought of various sizes and lengths, and copper is so malleable that it is easy to hammer it down into a good head. A riveted copper boiler well put together is of very smart and beautiful appearance, but to get seams tight is not at all easy. Hence, for toys, the ready-made brass tubing is far preferable, and nearly always used in the trade.

It will now be as well to speak of another kind of engine, the boiler being an independent matter. We have as yet only considered the single-acting cylinder, in which steam acts under, but not above, the piston, and the down-stroke is accomplished solely by the momentum of the flywheel. In double-action engines steam is admitted alternately to either side of the piston, which is thereby forced up and down. The momentum of the flywheel renders the movement more steady, and in addition carries the crank over its dead points and serves often as a driving wheel, having a strap, or being made with a cogged rim to drive the machinery to which it is attached. Steam is admitted to the piston just above, and then below, by one or two different arrangements to be presently described, but it has also to be alternately withdrawn or permitted to escape from one side after its work is done, while fresh steam from the boiler is being admitted to the other. This used to be done by a system of valves and levers, worked by a boy, who had to be very attentive, or the piston would have been blown right out of the cylinder, or other damage would have ensued. Then the engine was made to perform this work by tappets attached to the steam and exhaust valves, worked by an upright rod armed with pins and rods, which came into contact with the tappets or valve levers as the massive beam above oscillated like a gigantic scale beam upon its central pivot. These old heavy and clumsy engines are now quite out of date, and the slide valve has driven out the older and more complicated arrangements.

There is, however, another method which is much used for marine engines for model steamboats—an outcome of the very simple valve already described. The plan is so simple and acts so well that the toy maker will hardly find a better, nor is it difficult to rig up. A (Fig. 82, p. 178) is the face of a steam cylinder, with B C, a projecting piece on one side standing not quite so high as the central circular boss. These are drilled or cast hollow, and form steam ways, shown in the section, one leading to the top, the other to the bottom of the cylinder, into which they open. These steam ways do not meet, but are quite independent of each other, and each has its own opening, D and E, in the flat face of the central boss. Suppose the piston at the bottom of the cylinder, as shown in the section, it is evident that we must admit steam by the lower port in order to raise it, and at the same time the air or steam above it must be allowed free escape by the upper port, so that it may not become compressed as the piston rises, and thus interfere with its ascent.

This is beautifully accomplished by the steam block F, which is screwed down to the base plate of the engine. The block is solid, and accurately faced on the port side. G H are two semicircular or curved channels, the curve being struck from the centre, I, which carries the pin on which the cylinder oscillates. G we may call the steam port and H the exhaust port. A hole is bored from the back, or top, or bottom, as the case may be, into the curved steam port, and another into the exhaust port. Into the first the end of the steam pipe from the boiler passes, and the other is left open to the air, or a little jet pipe can be fitted into it. If we now pivot the cylinder to the pin I, so that the flat circular face of the boss is close to the block, it will be seen that when the cylinder is quite upright the little holes communicating with its interior will both be between the curved slots in the box, so that no communication is made between the ports in the block F and those of the

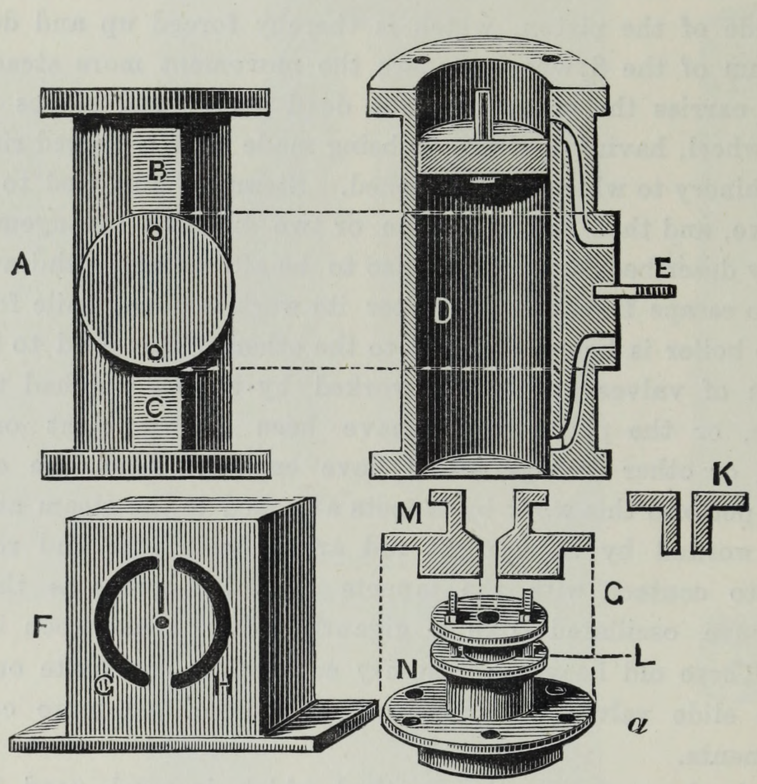


FIG. 82.—ARRANGEMENT OF DOUBLE ACTION CYLINDER ENGINES FOR STEAMBOAT.

cylinder. In such case the engine stands still. But if we now push the cylinder into a slanting position—the upper end leaning to the left—the upper port will be brought opposite the upper end of G in the block, and steam will enter and continue entering as long as the cylinder moves downward. But this brings the lower port of the cylinder opposite the curved steam port H, and, therefore, the lower side of the piston is in free communication with the air, as long as the upper side is being acted on by the steam. But presently the crank passes over its dead point, and the cylinder begins to incline in the opposite direction. Its lower port, therefore, now comes opposite the steam port of the block, and its upper port now communicates with the exhaust or escape port. The piston, therefore, is now driven upwards. Thus by the oscillation of the cylinder the ports are alternately opened and closed without the intervention of tappets or slide valve or any similar complication. This is, therefore, the simplest of all double action engines, and will answer for those called small power engines to drive lathes as well as for mere toy models.

Let us now consider the practical difficulties or otherwise of making an engine of this class. We may thus divide the work: Boring the cylinder; drilling the steam ways and ports; fitting the covers; and, facing the boss and the steam block, and so arranging them that they will work truly in contact without loss of steam during the oscillation of the cylinder. There is more than one way in which a cylinder may be bored, and the plan selected will depend on the appliances available for that purpose, of which appliances a lathe is almost essential, although it is not absolutely so, for cylinders have been bored without it. Nevertheless, it appears absurd for anyone to commence model making without at least a small lathe fitted with slide rest, and a few of the more ordinary chucks.

In the first place, look at the casting, and see which end of it seems the best and flattest. Remove with a file any excrescence above the general level, and render the entire end tolerably level, just sufficiently so to enable it to bed down well on a face plate or other chuck. Clamp it down on that end to the face plate if you have one suitable, or hold it in an American three jaw chuck, or drive it into a boxwood one, taking care in either case to bed the face alluded to well and truly on the face of the chuck, or, if you prefer it, and the bore is already a fairly smooth one, you can mount the cylinder on a short projecting arbor or stud turned on the boxwood chuck and made to fit tightly inside the cylinder; but turn the face of the chuck true and level at the base of such stud and drive the cylinder on till it beds fairly on the face so turned. You can also bring up the point of the back poppit, which will often fit and allow a cylinder to run truly upon it, and if so, this will vastly steady it. If mounted thus, you can now face up one of the ends and also the edge of both flanges. If mounted as just proposed, you can only get at one end to face it, which is practically what is required, because, in order to bore the cylinder, it must be mounted on one accurately faced end. Having turned, therefore, at least one end, you may take the cylinder out of the lathe, as you have an accurate surface to start with to commence boring. You have also not only one end turned, but one flange turned on the edge squarely and accurately, by which you can now remount the cylinder in a fresh chuck.

The American jaw chuck immensely facilitates engine making, because it will grip work centrally in a moment and hold it firmly, so that you may turn one flange and bore the cylinder at one operation. Then mount it on a mandril and face and finish the other flange. But suppose you have no such grip chuck, you need not be in any serious difficulty. After one end and flange are turned, make a boxwood chuck, hollow accurately to about ¼in. or ⅜in. deep, taking great care to level truly the bottom of the recess. Turn this to take the flange you have turned tightly and drive it in, not with hard blows, but with slow, steady, moderate taps with a hammer, until it is bedded down fairly on the bottom of the recess. This will hold it quite securely enough for boring it with a light cut. Supposing you have got thus far, you have but to fix an inside tool in the rest and take two cuts through to finish the bore nicely, unless the casting is full of hollow places, when three or four successive cuts will be needed to get a good surface. See that your rest is set for parallel work first of all, or you will bore the cylinder with a conical instead of a cylindrical interior.

I have pre-supposed the cylinder to be large enough to enable a slide-rest tool to enter it freely, but this will not be the case if it is not over ½in. bore in the rough casting. For such you must go to work in an altogether different manner, which, indeed, you may adopt with larger ones if preferred. Instead of using a slide-rest and fixed tool, a slight recess is turned just to start the cut truly, and a rose bit, or D bit, or half-round bit, as it is often called, is made to enter the turned recess, and, being centred on the back poppit point at its other end, is gradually advanced into the cut, being prevented from itself rotating by having a spanner or hand vice clamped upon its shank, which spanner will be on the top of the rest during the operation.

Some of the very small cylinders of ½in. bore are cast solid and drilled out, and the twist drills should do this truly. Sometimes, however, they are too keen in the edge for brass, but any drill will do the work with proper care. First mark and punch the centre at each end, and bore thence with a drill running in the lathe (for solid cylinders), but use a drill of $\frac{7}{16}$in. if you want a $\frac{1}{2}$in. hole. Then run a $\frac{1}{2}$in. bit or a reamer through, and true up the hole to size from one end only. In this case it is better to bore first and then turn up the flanges, having driven the cylinder for that purpose on a wooden mandril, so as not to injure the bore. Boring the cylinder of a small engine is not by any means the main difficulty to be overcome. To a turner it is a very simple operation, and with a grip chuck, slide rest, and inside tool, cylinders might be bored by any amateur with the utmost ease and rapidity. A well made rose bit, or D bit, will do the work quite as easily, so that a slide rest for cylinders up to $\frac{3}{4}$in., or even 1in. bore, is not a *sine quâ non.* A tolerably long experience, however, has taught me that it is not a good plan to work with inefficient tools or with an insufficient supply of apparatus. It is simply waste of time to do so, besides the risk incurred of spoiling good material; and although once in a way a lathe without a slide rest may do very well, it is far better, if possible, to add that useful appendage.

The cylinder covers are cast as circular discs, the lower one having merely to be turned with a flange to enter a little distance into the cylinder, and it is then faced up with a circular moulding or two, and drilled with from four to six holes for the screws by which it is attached. The upper cover is differently made. It is shown in Fig. 82, in section at M, and again below G, fitted complete with its gland or stuffing box. The part below the line L is in a single casting; that above it is the gland shown in section at K. The lower part is mounted by the flange, while the upper part is neatly faced and moulded (or left plain). Then, while still in the lathe, the central hole is drilled for the piston and partly enlarged to receive the gland, this enlargement being somewhat cup shaped at the bottom, but perpendicular in the sides. The whole cover may be turned at the same time as far as it can be got at. The work is now taken out of the chuck and reversed; and the chuck being turned out very accurately to receive it; the greatest care must be taken to bed down well the turned surface (a). The flange below is now turned and faced just to enter the cylinder as a good fit. It is perhaps safer to begin with this under side and flange, but there is this advantage in working in the other way, that after the smaller cavity in the chuck which received the flange has been used for the purpose, a touch or two of an inside tool will enlarge it to take the diameter of a, whereas, if we work the other way, we must turn down the entire face of the chuck before making a small cavity to hold the cylinder cover by its flange.

In all cases like this, in which both sides of an object have to be faced up, it is absolutely necessary to turn the bottom of the cavity in the chuck very true, and then to bed down upon it the face of the work which has been turned. If this is done, it is not generally of great consequence which side is first turned, but the matter should be nevertheless considered before commencing the work. Even in economising chucks a little forethought is of advantage, but this consideration is a secondary one compared with that of so arranging matters as to insure accuracy in the finished work. In the present case, if the two sides of the cover are not parallel planes, the central hole will not be at right angles to them both, and when the piston rod is in its place it will point to one side, and not take up a position in the axis of the cylinder. This will vastly increase friction and probably prevent the piston from moving at all, because it will jamb it against the side of the cylinder. The gland K may be held by its smaller end in a boxwood chuck while the top is being faced and the hole drilled for the piston rod; then the chuck cavity may be enlarged, the gland remounted with the other side outwards, and the lower part turned to fit easily, but nicely, the hollow turned to receive it. It is generally cupped a little at the bottom.

This gland serves to compress against and around the piston rod a little packing—greased tow—which is wound round it after it is in place. The gland, being slipped on over the rod, presses down this packing into the cup-shaped cavity of the cylinder cover, and compresses it so closely about the piston rod as to prevent even the slightest escape of steam. There are two modes of forcing down the gland. In the illustrations given two small steel rods are screwed into the cylinder cover and passed through holes in the gland. A pair of small nuts will hold all securely together and provide the requisite downward pressure. Instead of this, the outside of the gland and the inside of the cavity in which it fits are frequently cut with a screw thread, which is a very neat plan, and answers well if correctly done. But in a small engine this thread (inside) cannot be traced in a lathe, the hole not being sufficiently large to admit the chasing tool. This necessitates using a screw tap, and as it is not a thoroughfare hole which has to be threaded, it will need two taps at least to cut the screw, and they must be very fine in thread, finer than is usual for a tap of the diameter here required. Hence it will be found a far easier job to attach the gland to the cylinder cover by the method which is here described. The covers are attached to the cylinders by screws or small bolts and nuts, and screws and taps to suit them fitted in neat handles, or the little bolts and nuts beautifully finished can be bought ready for use.

The next process will be the facing of the boss on the steam cylinder—an important operation, upon the accuracy of which the working of the engine will mainly depend. This face must form a plane at right angles to that of the cylinder ends. If it is not thus placed a failure will be the result. With proper care, however, correctness may be easily insured. In the first place, turn the two flanges of the cylinder exactly the same size. Upon these the cylinder will rest in the chuck now to be prepared. Hollow out a boxwood chuck so that it will hold the cylinder laid flat down on it, and keep it tightly held. It should bed down in the chuck to its diametrical line or axis, and will look like Fig. 83.

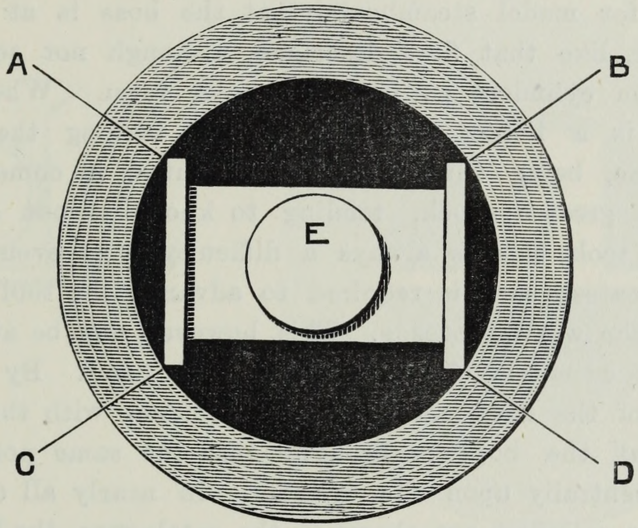


Fig. 83.—Cylinder Bedded Down in Chuck.

It is apparent from the drawing that it will touch at four points—A, B, C, D, which will suffice to hold it securely. See that the face, E, of the boss lies as true as possible with the face of the chuck, tapping the work in lightly at first till such is the case, and then bedding it down firmly. You can now face up the boss easily by hand with a round end tool, followed by a flat tool, or by help of the slide rest. Try it with a straight edge, that you may make sure you have neither hollowed it nor coned it in the least. It must be dead flat, and as smooth as tool can make it. Drill also at the same time a small central hole for the pivot, and turn the edge of the boss a little way to give it a neat finish—$\frac{1}{16}$in. to $\frac{1}{8}$in. will do, unless it projects further; anyhow, turn as much as you can to a square edge, do not round it off. Now drill the hole for the pin or pivot on which the cylinder will oscillate. For this purpose first hold a graver against it so that its point will cut a slight conical recess to guide the point of the drill. The latter should be fixed in a handle or held in a small hand vice or in a drill chuck, and its point presented to the work while it is in rotation. This will make a central hole quite square to the surface of the boss, which is essential to the working of the engine. The pin will be screwed into this hole after it has been tapped, or it may be driven in tightly or soldered, but the proper way is to screw it.

In this description the boss of the cylinder is supposed to be in the centre, equidistant from the two flanges, so that when mounted in a chuck in the way described the face of it can be turned true. But such is not always the case. It often happens, especially with engines not meant for model steamboats, that the boss is at the bottom of the cylinder, like that first described, although not so frequently in double action cylinders as in the simpler form. When this is the case there is a little more difficulty in turning the face of the boss, because, being further from the centre, it comes against the tool with a greater shock, tending to knock it out of the chuck. With hand tools this is always a difficulty, and even with a slide rest the greatest care is required to advance the tool by very slow degrees as the work proceeds. This, however, can be at once avoided by using an eccentric chuck, if such is at hand. By means of this the centre of the boss can be made coincident with that of the mandril, so that the boss is brought into the same position as if it were cast centrally upon the cylinder. In nearly all cases in which double-action cylinders are shown in the catalogues, the boss is central, so that no difficulty will be experienced in obtaining that form of casting. There is also a certain advantage in using cylinders of this pattern—viz., that the cylinder when at work is not top heavy, but nicely balanced, and, therefore, will work more smoothly when in action. The steam block may be filed, planed, or turned up to a true face.

It is quite a mistake to suppose that only circular objects can be satisfactorily worked in a lathe, and it is often advantageous to turn those of cubical form, as it secures the relative positions of the several planes. A set of dice, such as are used for playing backgammon, can easily be turned and made more quickly in this way, if a proper chuck is used, than by filing. A steam block is generally shaped like Fig. 84, p. 185 (B), which can be mounted in an ordinary boxwood chuck, as shown at C, when the centre of rotation is at A, and the piece is fixed by its corners so as to be easily faced up. But here the centre is not that, perhaps, on which it will be convenient to centre the pivot—it is rather low down at D, and therefore the hole for the pivot would have to be drilled afterwards. This need present no difficulty, however, if the drill be mounted in a drill chuck and the steam block brought against it by the cylinder of the back poppit, with its boring flange mounted on it as usual. Even with a hand drill there is no real difficulty.

It will, however, be often advantageous to mount such an object as this in order to bring any point central that we may wish to place in such position, and there are two other ways in which we can mount them in a lathe. First there is turners' cement, used upon a flange or flat chuck. This is a composition of pitch, resin, and brickdust, melted on the face of a wooden chuck, and the bit of brass is laid upon it while both are warm, and centred as may be required. In a few minutes it will be firmly fixed, and capable of bearing the action of the turning tool, if used with care. This is a most useful chuck in model making, as any shaped bit of metal can be thus mounted on the lathe, and any part of it can be brought to the line of centres. The other plan, also of great service, is to use solder to unite the piece of metal to the chuck. Both are to be heated, but the chuck itself need not be sufficiently so to melt the solder, which can be rubbed on its face with the soldering iron until the surface is well tinned. A brass chuck will take the tin better than one of cast iron, but either will do. Then the bit of metal, filed to a clean surface, is to be similarly tinned and heated till the

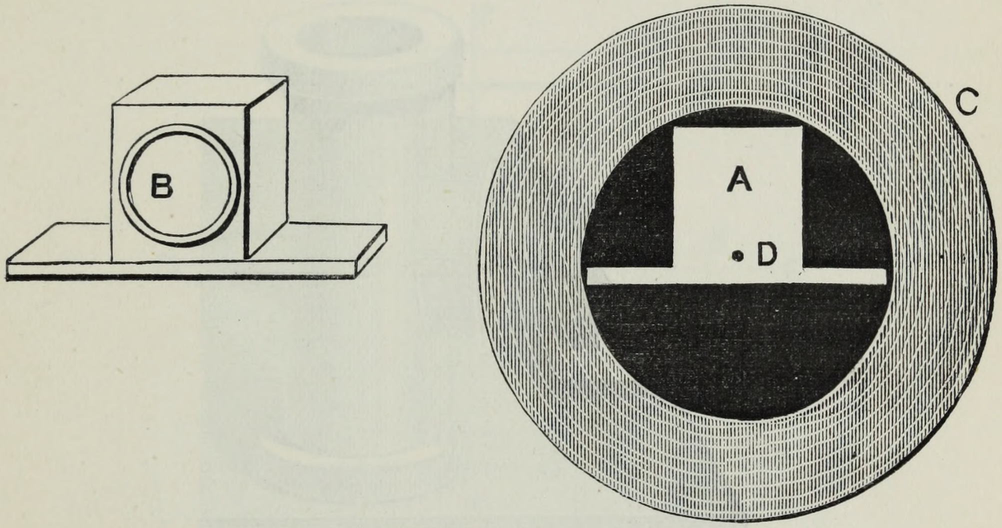


Fig. 84.—Steam Block: Ordinary Form and Mounted in Chuck.

tinning is in a melting condition upon it. It is then to be placed in position on the chuck, and in a few seconds it will be perfectly secure. In this way the steam block can be mounted and faced, drilled, and two concentric circles marked upon it with a point tool or graver to denote the position of the steam ways which have to be cut into it. These steam ways are drilled out and finished by means of a small chisel. If there is a drilling spindle at hand to fix in the slide rest they can be beautifully done before removing the piece from the lathe, the drill being driven from overhead, and the work caused to oscillate slowly to and fro, by taking hold of the lathe pulley and moving it by hand.

There is another way of turning the face of the boss on the steam

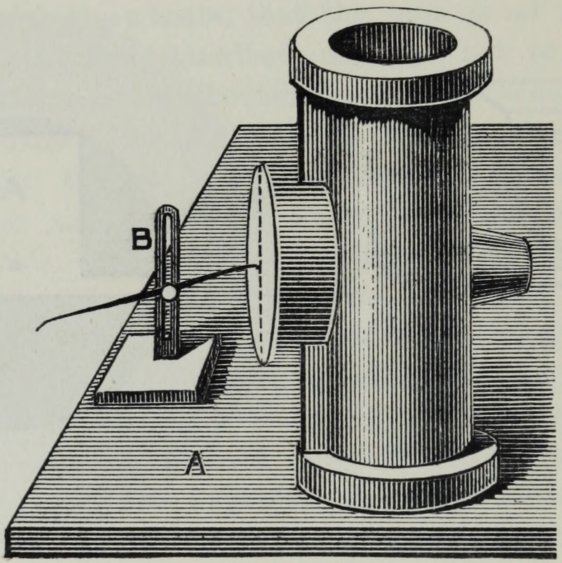


FIG. 85.—PLAN TO CENTRE CYLINDER, SHOWING SURFACE PLATE AND SCRIBER.

cylinder when it is placed centrally. In Lee's engine castings the cylinder has a projecting tenon exactly opposite to the boss, the end of which receives the centre screw by which the cylinder is kept close up to the steam block. Mr. Lee has exercised much forethought in planning all parts of his engines, to facilitate turning such as require it, and this tenon gives great assistance, in mounting a cylinder in quite a different manner from that described, and by which as correct practical results may be obtained. Figs. 85 and 86 represent such cylinder, and in turning it we have to get the line D E (Fig. 86), its horizontal axis at right angles to F G, its vertical axis, and the plane of A B perpendicular to D E. It is evident from the sketch that we may mount the cylinder between the centre points of the mandril and back poppit (I and K), and that, using a driver chuck, the pin of the driver will catch against it, and that it will thus become its own carrier, while C, the tenon, is being turned. Reversing it we shall get at the entire face (A B) as well as its edge, and be able to turn up the boss. In order correctly to centre the cylinder thus by its flange and tenon (and if there is no tenon by a centre hole punched in the cylinder at the opposite side of the boss), it ought, after the ends have been turned flat and true, to be placed upon a surface-plate A (Fig. 85), and a scriber brought up to it as at B, to mark a horizontal line on the face of the boss and on that of the tenon at exactly the same height. The plane on which these lines fall will be then parallel to that of the surface-plate and perpendicular to the axial plane of the cylinder. The hollow centres for the lathe points can then be easily found by a pair of compasses, and may be lightly punched and tested by mounting the cylinder upon them in the lathe, and giving it a turn by hand. Of course in using the surface plate and scriber, the cylinder is to be turned end for end on the surface plate until the true centre is found.

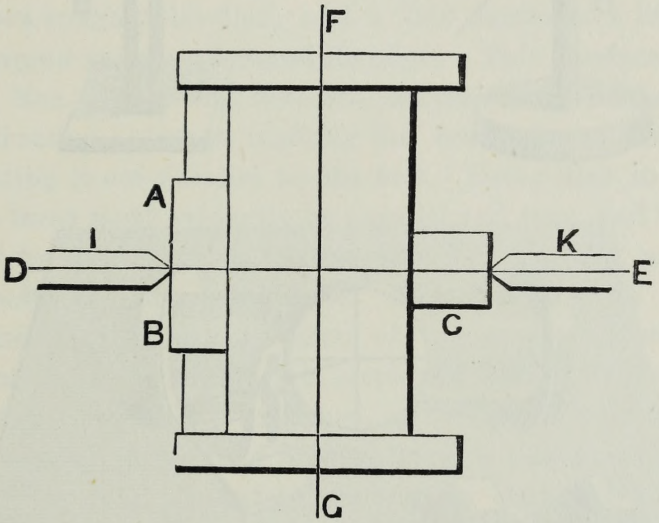


FIG. 86.—PLAN FOR TURNING CYLINDER.

We will now go a step further and show the use of the surface plate more perfectly. We have marked a line on the little face of the tenon and on that of the boss, and then by help of the compasses made a central mark upon it for the punch; but we can do this in another and more accurate way with the scriber, by laying down the cylinder as in Fig. 87, and crossing the first line by a second, turning the cylinder over and back till we get the line to bisect the first, then bringing round the scriber to the end of the tenon, we scratch a line upon it without altering the height of the scribing needle, holding also the cylinder, so that it shall not roll over in the least. It is generally laid on V blocks like A, which hold it and prevent it from rolling, or any little blocks may be placed on each side as lies upon its flanges upon the surface plate.

If model making is to be a hobby, the toy maker should most certainly obtain some sort of scribing block and plane table. For the latter a simple expedient is a carefully selected sheet of thick plate glass, which is almost a true plane, the surface plate proper being an expensive article. A scribing block may be cheaply purchased or home made, and all that is needed is some sort of stand with a level base, and a pedestal on which the scribing needle can be adjusted to any height likely to be required. B and C are simple forms, but there are many varieties, some depending on the lathe for their formation, others on the file and planer. Even a wooden block fitted up with an adjustable steel needle about $\frac{1}{16}$in. to $\frac{1}{8}$in. thick, and pointed,

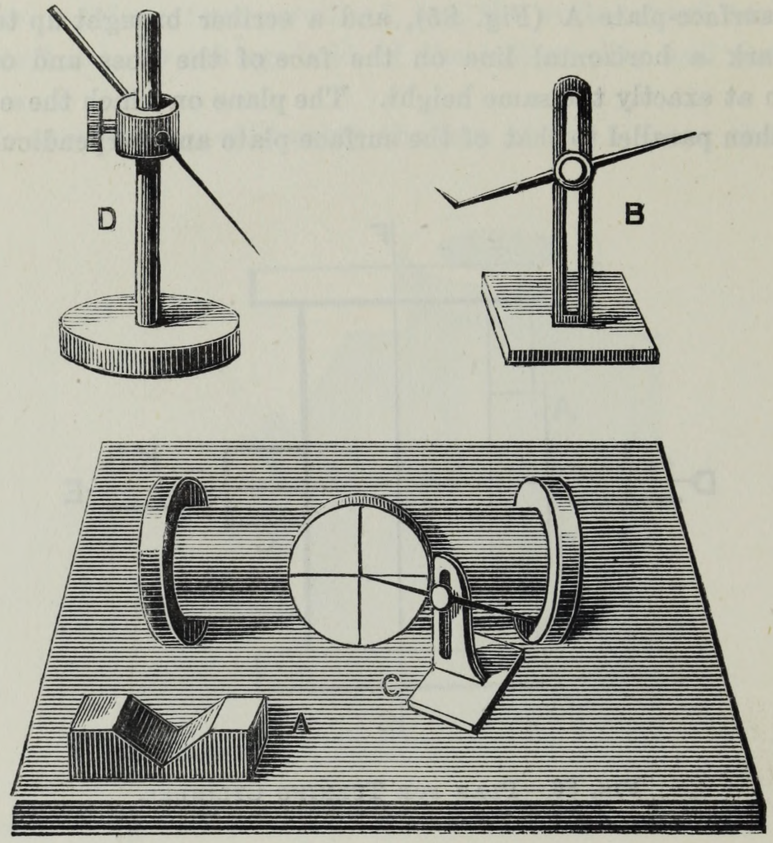
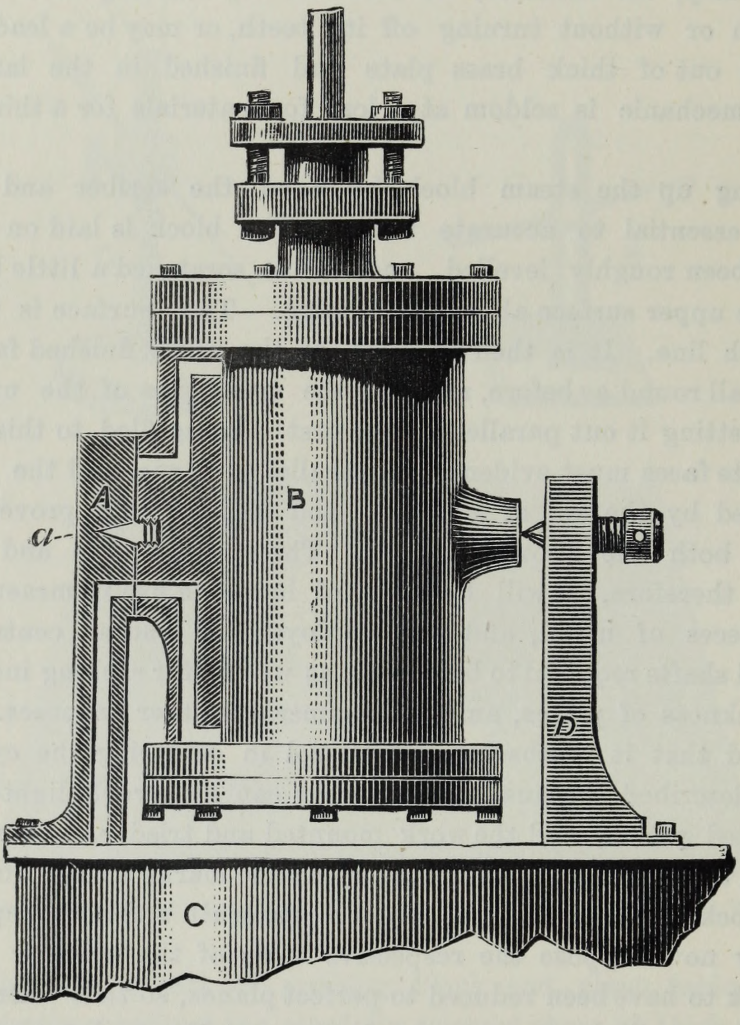


Fig. 87.—Marking Cylinder: Surface Plate, Scribers, and V Block.

may be pressed into service if cheapness is an object. In Fig. 87 (D) is shown a scribing block made of a turned boxwood base with a pedestal made of stout brass or iron rod, on which slides a boxwood block to carry the needle, which, like the block, is secured by a clamping screw. This can almost as easily be made of metal, and most amateur workshops will contain some odds and ends suitable for the purpose. The base may, for instance, be made of an old cogwheel faced up nicely, with or without turning off its teeth, or may be a lead casting, or chipped out of thick brass plate and finished in the lathe. An ingenious mechanic is seldom at a loss for materials for a thing of this sort.

In getting up the steam block by hand, the scriber and surface-plate are essential to accurate work. The block is laid on one side, which has been roughly levelled, and a line scratched a little below the level of the upper surface all round its edge. This surface is then filed true to such line. It is then reversed on the newly finished face, and a line drawn all round as before, marking the true edge of the upper surface, and setting it out parallel to the first. Being filed to this line the two opposite faces must evidently be parallel and true, and the edges are then worked by the aid of a square and file, till they prove at right angles to both the above surfaces. The surface-plate and scribing block are, therefore, it will be seen, of immense use in measuring and marking pieces of metal, and are employed for finding centre points of bars and shafts required to be turned, as well as for seeking inequalities in the thickness of plates, and for innumerable other purposes. It cannot be said that it is absolutely essential in centreing the cylinder in the way described, because centre points can be struck lightly with a finely pointed punch, and the work mounted and tried, and, if necessary, readjusted, till true; but the practical mechanic marks all his work by the scribing block, so as to leave no doubt of its truth and accuracy.

We may now suppose the respective faces of the cylinder boss and steam block to have been reduced to perfect planes, so that when working together there will be no escape of steam. Means have now to be provided for keeping these in close contact when all parts are put together. In the cylinder illustrated, which has a projecting tenon opposite to the boss, there is a centre already made during the process of turning to receive a centre screw on which the cylinder can oscillate. By means of this the faces of the steam block and boss can be readily adjusted, the block being, of course, permanently attached to the bed plate. In this case there is no need of a central screw in the block, a mere point projecting $\frac{1}{16}$th of an inch or less will amply suffice, a corresponding hollow being made in the face of the cylinder. Fig. 88 is a part section of such a cylinder and its attachments. It is represented as mounted on the top of the boiler C. D is the pedestal carrying the centre screw, A the steam block, and *a* the short point on that side upon which the cylinder B oscillates. Mounted thus, there will be no necessity for a steam pipe, as the steam way in the block communicates with the boiler direct, and the engine will cease working if the cylinder is held for a moment upright—this position cutting off communication between its interior and that of the boiler. Such mode of mounting an oscillating cylinder is much stronger than that used in the small single-acting engines, which oscillate on one pin only, and it is always used for double action cylinders for steamboats, which work in pairs, one on each side of a central steam block.



FIG, 88.—PART SECTION OF OSCILLATING CYLINDER AND ITS ATTACHMENTS.

There is no occasion to enter into details of the fly-wheel and crank-axle, as there is no practical difficulty about these, and much will depend on the design of the engine used. In a marine engine, for instance, with paddles, there is no fly-wheel, and two cylinders are required, so as to produce no dead points, as they are called—that is, the cranks being placed at right angles to each other, and the cylinders being of double action, the axle is being pulled round continuously, one crank acting fully when the other is on its dead point or neutral position. In screw steamers a small heavy fly-wheel is often added to the crank axle to give impetus to the screw and assist in overcoming the resistance to its rotation offered by the water. Again, in the case of locomotive engines, the smallest are made with one single-action cylinder, and seldom work well. The others have a pair of single-action ones working a pair of cranks at right angles to each other. Here, of course, the driving wheels are the flywheels, and there is no dead point, so that these small engines should work well. But for anything larger the pair of double-action cylinders, oscillating or slide valve, are far preferable, as with these there is ample power, and the force tending to move the engine is constant. As regards the particular design of engine, much will probably depend upon the castings offered for sale. They may be horizontal engines, with bedplate, or vertical to fit on the boiler or table, with cylinder upright or reversed, the horizontal appearing to be the most generally used, but for this the cylinder should be formed with a flat plate below, or with lugs to bed down on the foundation plate.

CHAPTER XX.

TOYS WORKED BY STEAM—SLIDE VALVE ENGINES.

THESE are rather more difficult to make, but are always considered a superior class of engine to those previously described. They are almost universally used where steam power is adopted to drive machinery, as well as for railway locomotives and steamboats, although the engines of the latter are usually direct acting, with oscillating cylinders—*i.e.*, there is no connecting-rod intervening between the piston rod and crank. To accommodate the motion of the latter, therefore, it is plain that the cylinder must be allowed to oscillate upon pivots, or trunnions, as they are called when of large size. Naturally it would occur to the mind of the engineer or model maker to admit steam at the trunnion, either as explained and illustrated here, or in some equally simple and efficacious manner; but in nearly all cases the slide valve proves the better expedient, and is more easily kept in working order. Moreover, it gives power to use steam expansively—*i.e.*, to admit and cut it off before the entire stroke of the piston has been completed, leaving the greater part of the stroke to be accomplished by the expansion of the steam in the cylinder itself.

Although it might perhaps suffice, as far as mere toymaking is concerned, to carry the subject of engine making no further than I have already done, merely describing some others with oscillating cylinders, yet it would be a pity not to describe the slide valve engine and mode of constructing it. The boring of the cylinder and fitting the covers will be precisely similar to what is required in the case of double-action oscillating engines, and the steam ways drilled or cast in the substance of the cylinder will also be similar, ending, however, in a rectangular boss instead of a round one. But there will now be in the face of such box a third port, intermediate between the other two, and not directly connected with either of them, but with an escape hole in one side of the boss. All the three ports will have to be neatly chisselled to an oblong form, as delineated here in Fig. 89, at A. If the steam ways are not cored out in the casting—and they seldom are, except in engines of larger size—they should be drilled out as large as the substance of the cylinder will allow; or two should be drilled side by side, which is often the better plan. This drilling requires much care lest the drill swerve and run out of its course into the inside of the cylinder or otherwise. The best way to insure a straight course is to drill in the lathe, and here again the scribing block and surface plate will come into requisition to mark the position of the hole or holes. Fig. 90 represents the cylinder laid on

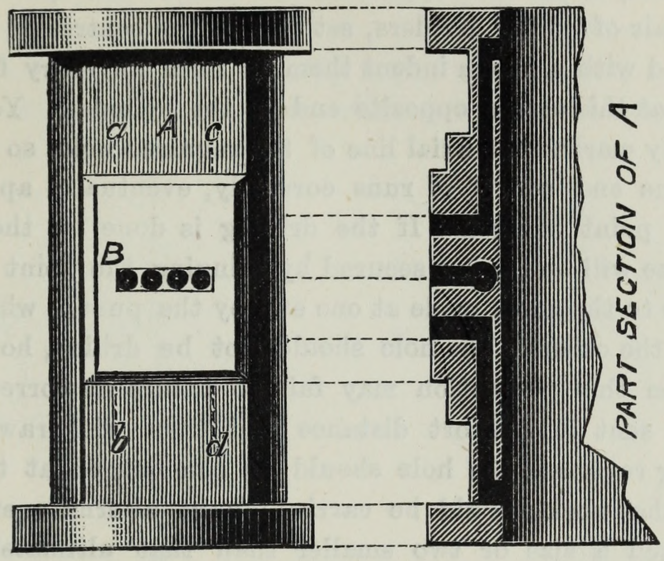


FIG. 89.—CYLINDER FOR SLIDE VALVE ENGINE.

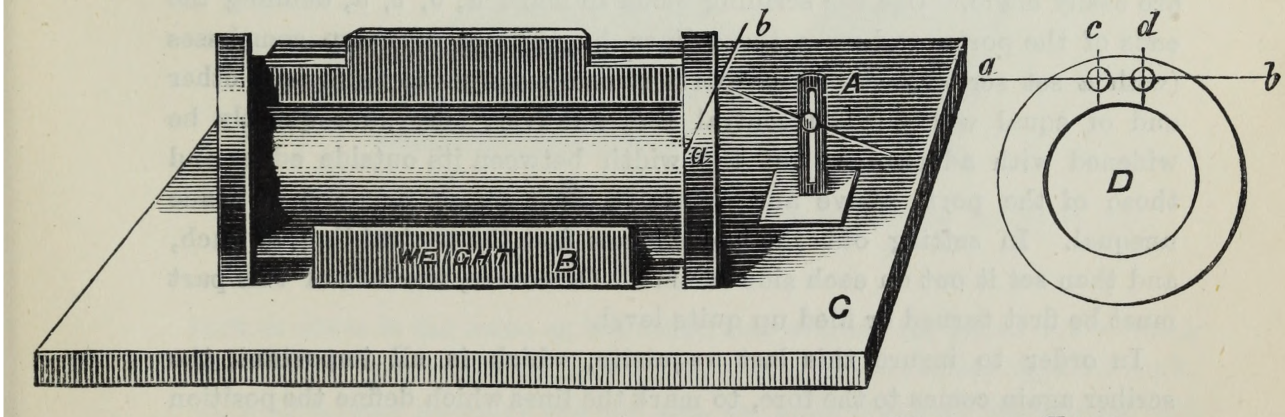


FIG. 90.—POSITION OF CYLINDER ON SURFACE PLATE, METHOD OF USING SCRIBER, &c.

the surface plate C, and secured by blocks B, of lead, to prevent it from rolling or shifting. A shows the scriber in one of its two positions, by which a line is to be drawn, *a b*, on the turned ends of the cylinder. Such lines will be in precisely the same relative position. At D the line is again marked, as it would appear on the end of the cylinders. Upon *a b*, with a pair of spring dividers, set off *c d*, the centres of the holes to be drilled, and with a punch indent them to form an entry for the drill point. Repeat this at the opposite end of the cylinder. You will now have distinctly marked the axial line of the required hole, so that a drill entered at one end will, if it runs correctly, eventually appear at the other, at the point marked. If the drilling is done on the lathe, this straight course will be readily secured by bringing the point of the back poppet centre to the mark made at one end by the punch, while the drill is entered at the other. The hole should not be drilled, however, in a hurry, or even this precaution may fail to insure its correct progress. It should be sent in a short distance and then withdrawn, and, the cylinder being reversed, the hole should be commenced at the opposite end. Then the work should be carried on at alternate ends, a drill being also used a size or two smaller than that ultimately required. These holes are not to meet and so form a single continuous steam way, but each must cease at the port nearest to the end at which it was commenced. It will therefore be safer practice to cut these two ports roughly before drilling to meet them. They will be drilled first of all like B, Fig. 89, and then cut out with a small chisel made for the purpose of hard steel. These can be bought at the model shops, but are easily made. Use the scribing block to mark *a*, *b*, *c*, *d*, defining the ends of the ports, and upon these lines, by the aid of sharp compasses (with a set screw), set off the ports at equal distances from each other and of equal width. The central one, however, may subsequently be widened with advantage, but the width between its outside edges and those of the ports above and below it must on no account be made unequal. In setting out the ports draw first the central line of each, and then set it out on each side of this. Of course, the face of this part must be first turned or filed up quite level.

In order to insure this last requisite, which is all important, the scriber again comes to the fore, to mark the lines which define the position of the plane surface. Fig. 91, A, B, and C, show what is to be done. The face, *c*, *d*, of the boss must be at right angles to the diameter, *a*, *b*, as seen at A, not as drawn at B, which is a fault often committed by careless workmen. Hence the cylinder is adjusted on the surface plate to bring this face in position as nearly as possible in the rough casting, and secured, as before, by a couple of lead weights and a line, *c*, *d*, at C, Fig. 91, marked as a guide to the file.

We may now consider the cylinder bored and the ports made. The next operation will therefore be the turning the cylinder covers and making the stuffing box or gland through which the piston rod is to work. This, however, has been described as a part of the double-acting oscillating engine. It is a simple bit of lathe work, which should not present any great difficulty to the toy maker, who can use a hand turning tool. The bottom cover is the same as the other, but without the gland and stuffing box, unless, as sometimes happens, the piston rod is carried right through, working a force pump at one end and the main crank of the driving axle at the other. We may pass on, therefore, to the slide valve and its adjuncts. As yet the steam ways that were drilled are open at each end, and do not communicate with the inside of the cylinder. The ends must therefore be plugged with brass wire screwed or driven in tightly and faced off flush, and ports cut just inside the cylinder to communicate with

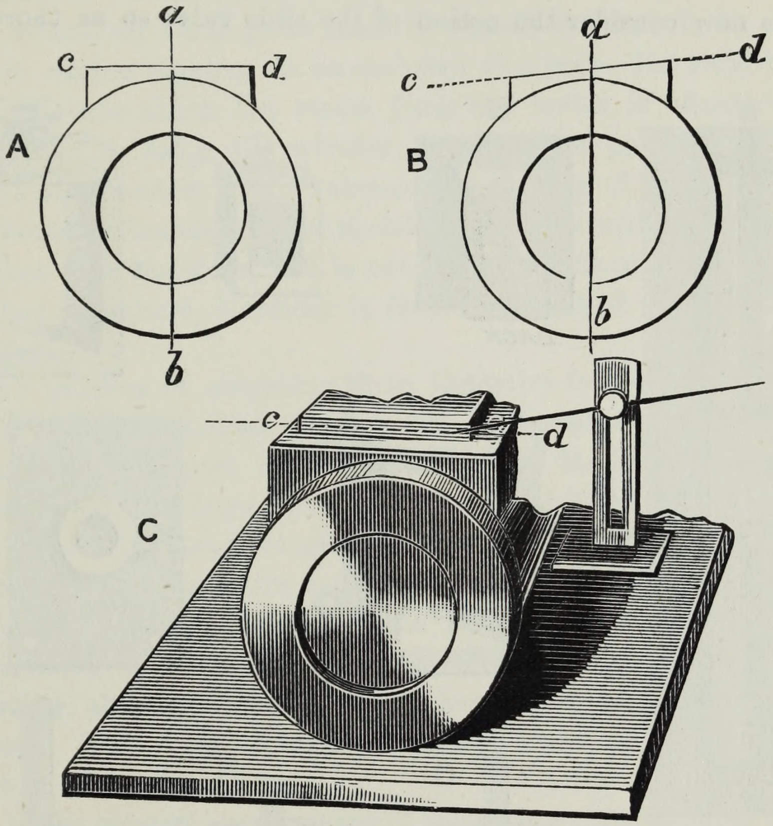


FIG. 91.—SLIDE VALVE—METHOD OF CUTTING THE STEAM HOLES IN THE CYLINDER.

the drilled steam way. These can be drilled from the inside by a little management of the drill spindle, or cut with a small chisel, or drilled right through from the outside, but if this is done there will be the necessity for plugging the outside of the hole so made, and it is better to avoid this if possible. There is little difficulty in drilling from inside, only there is not much room to work; *a b*, Fig. 92, show the plugs (black); *c d*, the inside ports; *e f*, the steam ports, and *g* the exhaust port of the valve face of the cylinder, all in section, which will make the matter clear to the reader.

Let us now consider the action of the slide valve so as thoroughly to understand what its office is. It consists of a kind of box, with a flat flange (B, Fig. 92), generally represented, however, in a model engine by a square bit of brass, about $\frac{1}{4}$in. thick, cut out in the inside like C. The use of the slide is to connect two ports on the valve face together. Suppose such a box turned upside down upon the ports, and slid upwards until the upper and central ports both fall inside it. These would now

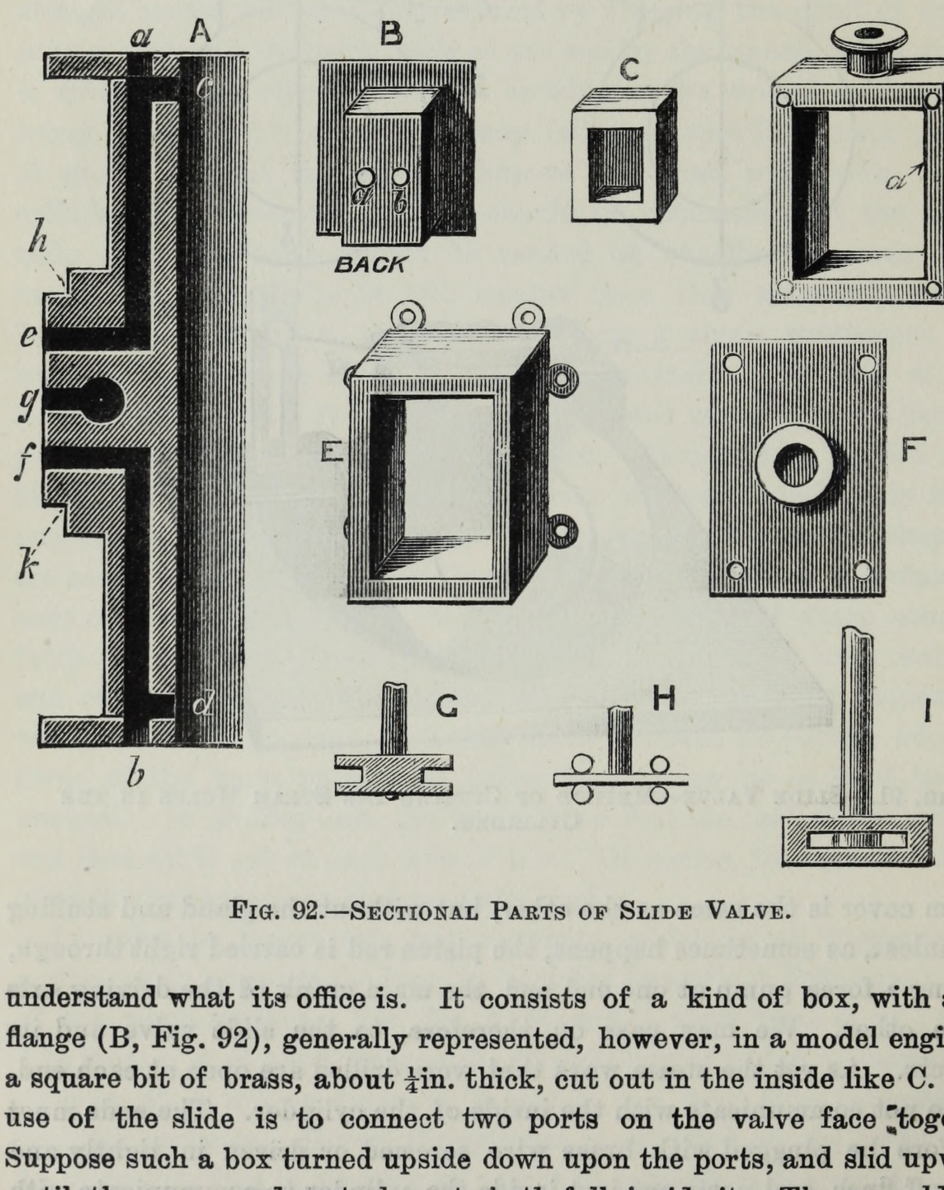


Fig. 92.—Sectional Parts of Slide Valve.

be connected as one steam way, while the lower port would be outside the box, and therefore remain open. Now let the box or valve be slid downwards until the upper port is clear; the two lower ones would be in connection with each other. Thus the central or exhaust port is always open to the inside of the box, and is alternately made to communicate with the two steam ports by sliding the valve up and down. It is evident that in designing these ports we must make this valve of such a size as to comprehend two ports and leave out the third, but the flange or flat face outside the hollow part must also be of such width that when the valve is central all three ports shall be exactly covered by it. All this part of the engine requires to be enclosed in a case—the valve-casing as it is called—into which the steam from the boiler is admitted, to be thence allowed to enter the cylinder by whichever port is left open by the action of the slide. This valve-casing consists of a box, D, open at top and bottom. Sometimes, for models, it is made with a back, however, in one piece with the sides, but is not so easy to fit up. At the top is a stuffing box and gland, identical in form with that of the cylinder cover, but smaller.

For the purpose of attaching it to the valve face of the cylinder, the casing in models is drilled through the thickness of the sides for long bolts, as seen at D, such bolts also holding on the back of the case; or it may be made with lugs for short bolts, as at E, or flanged all round, the first plan being usual in small models. There should in any case be a rebate, seen at *h*, *k*, in the section of the steam ports (Fig. 92), fitting the inside of the hollow casing, so as to keep it accurately in position while inserting the bolts to secure it. F (Fig. 92) is the back of the valve casing, showing a central hole where there is generally a boss or projection. This hole is tapped to receive the end of the steampipe from the boiler.

Such is the general arrangement of the slide valve, which is worked by its valve rod. This rod, passing as it does through the stuffing box of the casing, must not be attached rigidly to the slide valve, or it might lift it from the port faces, against which it has to work steam tight. The valve is actually kept against the port faces by the pressure of the steam on its back, and therefore the valve rod requires to be so fitted as to allow a little play. A simple plan is to make the end of the rod like G, and to put a pair of short pins, *a b* of B, in the back of the valve over which the notches in G will fit easily, or there may be four such pins as at H, or the end of the rod can be slotted like I, and fit over a rectangular projection or two pins. There is no play necessary except such as to allow the valve to bed fairly against the port face, so that it shall not be drawn away in the least by the up and down traverse of the valve rod.

Indeed, the less side play the better, and it will be an advantage to make the width of the slide valve as nearly as possible that of the inside of the steam chest or valve casing, this forming a guide for the accurate to and fro motion of the valve. The form I of valve rod common in locomotives is made in large engines to embrace within the slot, not a mere projection, but the whole back of the valve, which is sketched at B, and the rod is often repeated below the square frame and passed through a second stuffing box, thus giving a very steady motion to the valve. There is not much difficulty to be apprehended in fitting the valve casing, the main point to be attended to being accurate facing of all bearing surfaces, which ought to fit quite tight, but may be assisted by a washer of sheet lead or a little smear of white or red lead when put together. F may be faced in the lathe and the boss turned, drilled, and tapped while so mounted; the flange chuck, with cement or solder, being the best to use. All surfaces should be tested on a surface plate, and not allowed to pass muster if at all defective; after being fitted they can be ground a little with emery and oil, or a smooth plate of iron or brass, not on the surface plate, or it will be soon spoilt; a very slight grinding only ought to be needed. All these parts, too, ought to be lined out with the scribing block, so as to insure the parallelism of their opposite faces, as for instance those at D at Fig. 92, marked *a b*. Careful lining out saves a world of trouble and insures a good fit.

Pistons were at one time invariably made steam tight by means of a packing of greased hemp or tow wound round them in a groove or grooves turned to receive it. For toy engines the plan answers sufficiently well, but in the smaller ones even this light packing is too much, owing to the friction which it creates, and the pistons have to be left wholly without packing, even though, no doubt, steam frequently passes by them, an evil which reduces power to a minimum. But loss of power or entire stoppage of the engine is the only choice left to the model maker, who is made to learn in a very practical way the rather troublesome doctrine of frictional resistance.

When, however, we come to the construction of toys which are almost useful machines, and propose to make engines of 1½in. to 2in. bore, the pistons may be made with what is called metallic packing, *i.e.*, with one or more rings of metal cut through and allowed to spring open, the cut in one being placed opposite the solid part of the next. There are a great many ways of accomplishing this, some of which, however excellent, are far too complicated for adoption in toy engines. For these it will suffice to turn a rectangular groove on the edge of the piston $\frac{1}{8}$in. deep, to receive the packing rings, like Fig. 93. The rings are of steel, $\frac{1}{4}$in. each way, put on a mandril and turned to fit the cylinder tightly, being also reduced in thickness so that either one by itself or two together will fit into the groove in the solid piston. Of course, if two are used, the groove must be made sufficiently wide to receive them. They are, after being turned, sawn through and sprung open sufficiently to allow them to be got into place. They will then be found to tend to spring open, and so fit the cylinder truly.

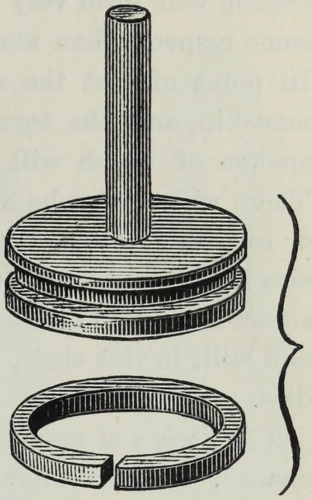


Fig. 93.—Piston and Ring.

Another way to arrange the packing is to turn the piston with a rebate instead of a groove, like Fig. 94, and then to add a separate disc or flange, securing it by a nut on the piston rod, or by three screws tapped into the piston. In this figure, A is the piston and part of its rod, B the lower flange, C the nut, the same flange being also shown with three screw holes for its attachment. The whole is shown again at E in section, with the rings *a* *b* in place. By this method it is far easier to put the rings in, because they can be slipped over the rebate and turned up true in place after having been sawn through and sprung open. If a bit of leather is put as a washer above and below the rings, they will be held firmly enough by screwing on the flange to allow them to be turned; this can be removed afterwards.

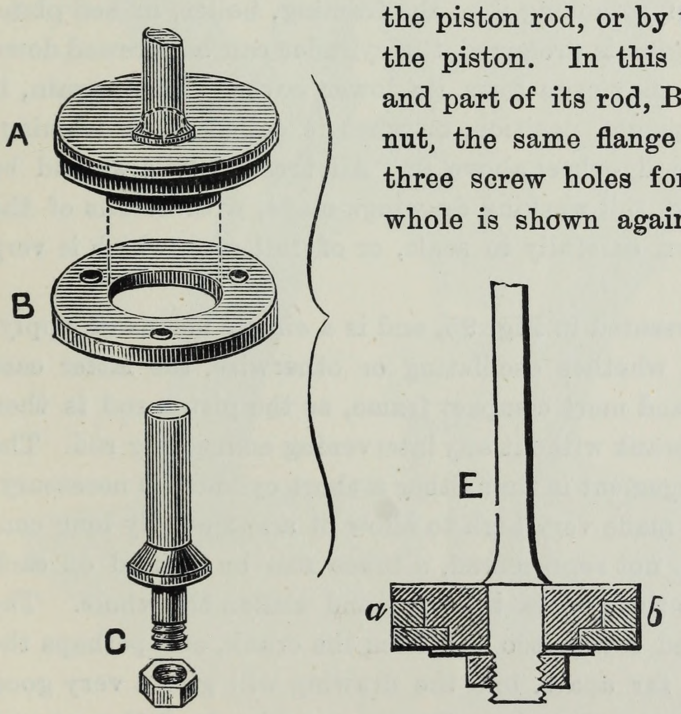


Fig. 94.—Arrangement of Packing, with Flange and Nut.

The packing rings will be more likely to spring open properly if hammered on the inside before being sawn through, as the metal is thereby expanded and in a state of tension. The outside of the ring during the process should be allowed to rest on a block of hard wood, so as to concentrate the blows more completely upon the inside surface. Hammered brass of square section will form very good springs for pistons, and is easier to work in some respects than steel; cast iron is also used in engines of large size. In point of fact the material is probably less important than the workmanship, and the toymaker may very well use any one of the metals spoken of which will form a spring, and may chance to be at hand. There will seldom be any necessity for turning the piston rod of a model or toy, as wire—steel as well as iron—may be had, drawn bright, of any size likely to be needed. This should be annealed at the end where a screw is desired, as it is rendered very hard by the process of drawing, and will, in this state, unnecessarily try the temper of the screw plate or dies.

The design of an engine should be settled before the cylinder is purchased, because some special appliance may be required by which to secure the latter in position. If intended for a horizontal engine or locomotive, the cylinder must be cast with lugs, or with a flat plate on one side, for the purpose of attaching it to the framing, boiler, or bed plate. If, however, a beam engine is preferred, the cylinder can be screwed down to the bed plate, which may even form its lower cover. Then, again, it may be fitted in an upright position, on what is called an A framing, with the crank axle and fly-wheel above it. All these details should be settled beforehand, and full working drawings made, with details of the various parts all drawn carefully to scale, or of full size, which is very much better.

The A frame is represented in Fig. 95, and is a simple means of applying a vertical cylinder, whether oscillating or otherwise, the latter case needing a much lower and more compact frame, as the piston rod is then attached direct to the crank without any intervening connecting rod. The only fault of this arrangement is that either a short cylinder is necessary, or the frame must be made very high to allow of a sufficiently long connecting rod. Although not represented, a brace can be carried on each side from A to B to tie the frames together and stiffen the whole. The eccentric is represented rather too far from the crank, and perhaps the two A frames are too far apart, but the drawing will give a very good idea of this kind of engine frame, and serve as a hint in fitting up any cylinder which has no special plate or lugs for securing it to the bed plate in a horizontal position. C and D are of course the guides, sliding up and down in the slots made to receive them in the thin web cast between the main uprights of this frame. With an oscillating cylinder of double action, like that previously described, the eccentric and also the connect-

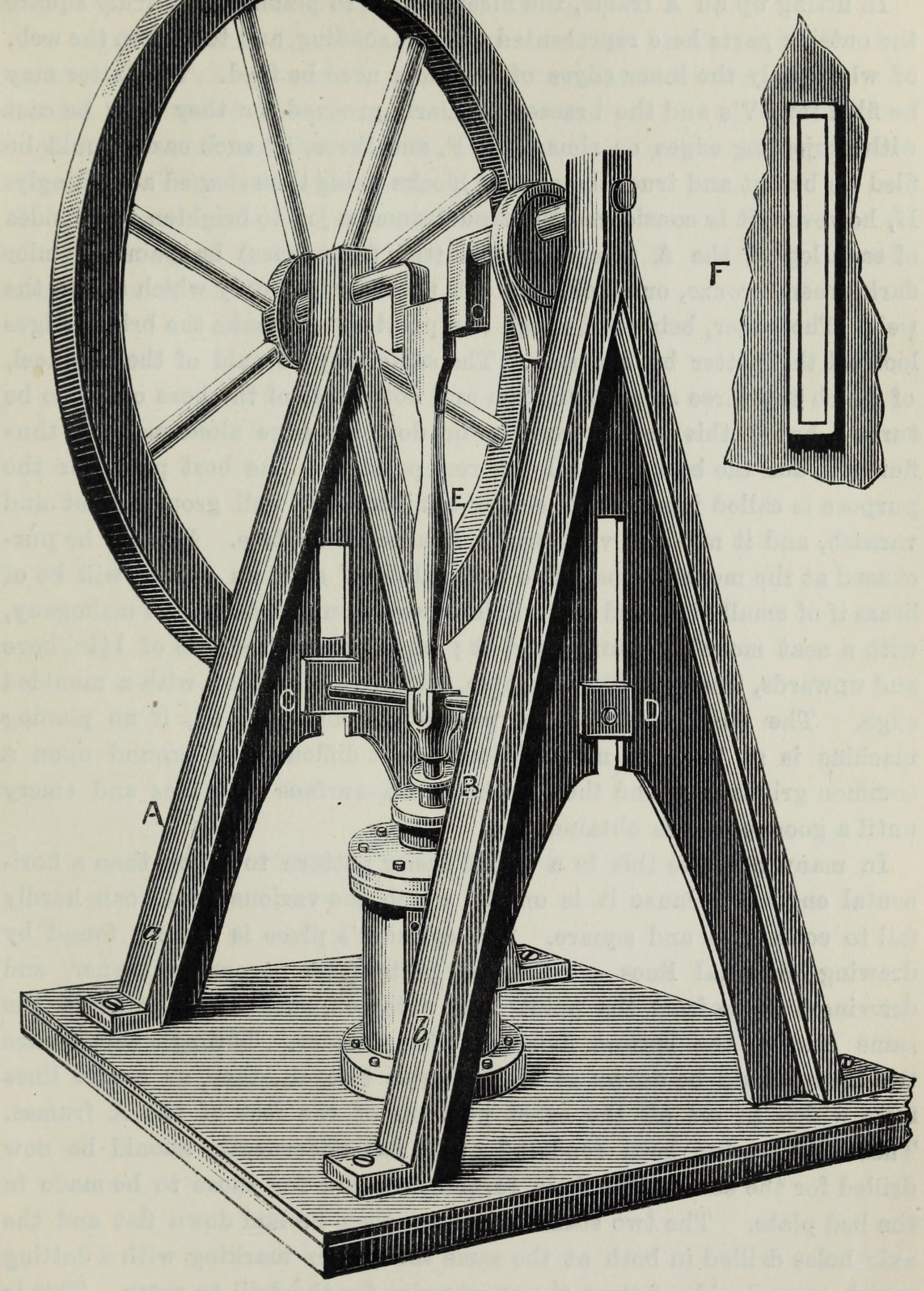


FIG. 95.—VERTICAL CYLINDER ENGINE ON "A" FRAME.

ing rod, E, would not be necessary, and in this case a very good engine might be made of this pattern to work a small lathe or sewing machine.

In fitting up an A frame, the nicer plan is to plane or file truly square the outside parts here represented without shading, and to darken the web, of which only the inner edges of the slots need be filed. The latter may be filed into V's and the brasses similarly grooved, or they may be cast with projecting edges or rims, like F, and these, in such case, would be filed up bright and true, the sliding blocks being then shaped accordingly. If, however, it is considered too troublesome a job to brighten three sides of each leg of the A pieces, let *a b* (the front ones) be painted a nice dark green, bronze, or black, and file up the edges only which adjoin the web. The latter, being left rough and painted, will make the bright edges look all the better by contrast. The same may be said of the flywheel, of which the three sides of the rim and both sides of the boss ought to be turned, but if this cannot readily be done the edge alone may be thus finished, and the boss and all the rest painted. The best paint for the purpose is called japan—it is simply a mixture of well ground paint and varnish, and it makes a very bright handsome surface. It may be purchased at the model shops. The base plate of such an engine will be of brass if of small size, and this will look well mounted on a bit of mahogany, with a neat moulding run round it ; but if the cylinder is of 1½in. bore and upwards, iron will be preferable, which can be cast with a moulded edge. The surface should be planed to look well, or, if no planing machine is at hand, it may without great difficulty be ground upon a common grindstone, and then worked to a surface with files and emery until a good polish is obtained.

In many respects this is a much easier pattern to fit up than a horizontal engine, because it is one in which the various parts can hardly fail to come true and square. The cylinder's place is readily found by drawing diagonal lines on the bed plate from corner to corner, and drawing a circle from the point thus obtained, such circle being of the same size as the bottom flange of the cylinder. Through this centre two lines should be drawn at right angles to each other, as centre lines from which to set off the exact position of the feet of the A frames. These feet having been rendered quite flat underneath, should be now drilled for the screws, the hole forming a guide for those to be made in the bed plate. The two standards must then be laid down flat and the axle holes drilled in both at the same time, after marking with a dotting punch on each side of them the exact point for the drill to enter. This is quite sufficient in a mere model, but for anything of larger size the tops of the frame have separate brasses fitted to them. In the present case an inspection of the drawing will show that the engine can be put together very easily without these separate split bearings, the flywheel being keyed on after the whole has been set up.

The sliding blocks, C and D, are merely fitted to the ends of the long turned bar or cross head, which at the same time acts as the pin on which the fork of the piston rod and the boss of the connecting rod are pivoted. The web between the sides of the frame is often pierced and made to assume an ornamental character.

It is easy to make patterns of these standards to suit the taste of the toy maker, and castings will then cost a mere trifle, whether of iron, brass, or gun-metal.

CHAPTER XXI.

TOYS WORKED BY STEAM.—ECCENTRIC AND CRANK TURNING.

It will be as well in this chapter to give a few details of lathe work required to be done on the eccentric and crank. The former is merely a disc of iron or brass fixed to the crank axle, the hole for such axle not being made through its centre, but a short distance from it. The distance equals half the length of the stroke or travel of the slide valve over its ports. This disc is surrounded by a hoop of brass nicely fitted to it. The hoop is made in two parts in large engines, but for models it will do in one. A rod screwed into one part of the hoop goes to the valve either direct or with an intervening quadrant, link motion, or lever. The motion of an eccentric is very smooth and quiet, and is always used to actuate slide valves of engines, and very generally in place of a crank where the travel required is but short. The disc of the eccentric being itself circular can only be turned in one of two ways. It can have a hole made through its geometrical centre, and then be mounted upon an arbor, and faced on its edge and sides, or it can be placed in a wooden or other chuck to about the depth of half its thickness, and one flat side can then be turned, and also the edge as far as it can be got at. Then the turned part being mounted in a fresh chuck recessed to take it, the other half can be got at, and if when it is mounted for the second time it is not driven into the chuck so far as to conceal the already turned edge, this will be a sufficient guide, and the work can thus be finished perfectly. But as there must be a groove turned in the edge, or the edge must be turned to a rebate, it is easier to manage when mounted on a spindle. There is, however, still one other plan, and that is cement or solder, which is very fit for a purpose of this kind, where a difficulty in means of chucking presents itself.

The only reason that exists for preferring a chuck in the present instance to a spindle, is that the hole by which it is thus mounted will not serve subsequently; and the second hole which has to be made may, if at all near to the first, run into it and spoil its appearance. An eccentric can indeed be turned like the pin of a crank (of which it is actually only a large edition), after it is mounted upon its axle by a hole eccentric to its geometrical centre; but, perhaps, it is hardly to be considered an easy method, or one suited to the toy engine. I shall speak of it by-and-bye, when treating of the turning of the crank axle.

The hoop or ring of the eccentric, if made with a projecting part to receive the end of its rod, or if made with lugs (Fig. 96, *a*, and *b*), cannot evidently be turned entirely on the outside, but only bored out accurately. The usual way is to mould the eccentric hoop something like Fig. 96, so that the two flats, *a b*, may be turned up bright, while the rest of the brass is finished by dipping, leaving it rough, but bright and clean. This dipping is largely used to finish surfaces of brass or gun metal, either of which is inserted for a few moments only in nitric acid, and then well washed in clean water and brushed with a wire brush. The sort of surface thus produced is very effective when brought into juxtaposition with parts which have been finished in the lathe. All bright work should have a coat of lacquer applied with a brush while the metal is warm to protect it from the action of the atmosphere. Brass lacquer of various tints, more or less golden in character, can be readily procured at the tool shops. If the metal be heated until it is just too hot to hold, this lacquer will dry directly. It must be laid on thinly and rapidly, otherwise it is sure to run, and it will then become streaky. It ought to be quite transparent and scarcely appear like a varnish laid on, but rather as if it was itself the outside skin of the metal.

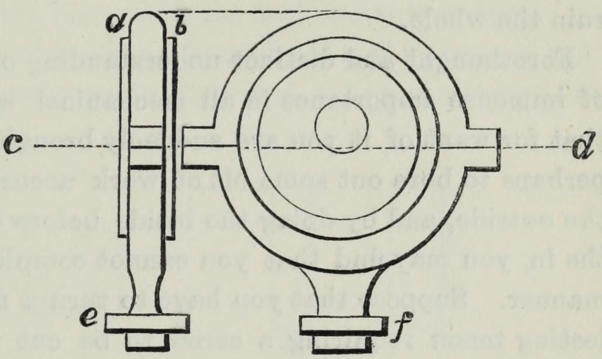


FIG. 96.—ECCENTRIC AND HOOP.

In small engine models the casting of this part is generally in one piece, which is bored out and turned, and then divided in the line *c*, *d*, Fig. 96, with a thin metal saw. This must be mounted on a chuck and bored, but it is as well first of all to drive it on a mandril of wood or metal, wood being preferable, such as the nose of a chuck turned down to enter it tightly, and then to face up one or both of the flat sides. This will enable the piece when put inside a chuck ready to be bored to be bedded down quite flat and true on the bottom thereof, so that the inside will be rendered truly at right angles to the sides when bored, and if this operation is done by hand, as it will be in the case of small models, care must then be taken to get it true, or the eccentric rod will stand at an angle instead of perpendicular to the sides of the hoop, and will not work the valve properly. The whole secret of success in this and similar mechanical work consists in attention to accuracy in little details. Conical holes instead of cylindrical ones, very slight deviation from the square fitting of parts, a little carelessness in chucking or in turning some detail which may seem of no great importance, will almost invariably ruin the whole.

Forethought and distinct understanding of what you have to do is also of immense importance in all mechanical work. You may find perhaps that for want of it you are suddenly brought to a standstill. You have perhaps to bore out some bit of work accurately and also to shape it on the outside, and by doing the inside before the out or the outside before the in, you may find that you cannot complete the job in a satisfactory manner. Suppose that you have to turn a round metal ball with a projecting tenon requiring a screw to be cut upon it: if you turn the ball first, holding the forging by its tenon, you will have to turn the latter as well as you can to size by the aid of frequent measuring with callipers, and at last you must cut it off before you can screw it. Now you have to screw the ball in a vice or to fit it in a chuck, but the first will damage it and the second is not easy, as a ball is a thing that does not fit and hold very tightly. The fact is, the operation is better reversed. Put the piece between centres, and turn the tenon and rough down the ball, just to give it something like its proper shape and to clean off the skin. Then you will not hurt it by gripping it in a vice to cut the screw, or you can trace this by hand in the lathe, the tenon being next the back centre. After having cut the thread and made the shoulder behind it quite true, fit it by the screw into a boxwood chuck drilled and tapped to receive it, or into a brass chuck, if you have one. The box will hold it, however, quite securely, and you can then with a graver turn up the ball very easily, and make a well-finished job of it.

This chucking by means of its own screwed tenon is very serviceable indeed in model making. The better way is to work all such tenons to standard sizes of which you have taps or chasers, and to keep a set of brass plugs fitted into a main chuck and tapped each with a screw of the sizes most generally used—rising by 32nds from $\frac{1}{16}$in. to $\frac{1}{2}$in. Matching this set there should also be one with short projecting screws of steel of similar pitches, on which to mount and finish nuts and any pieces which can be first drilled and tapped. We have an instance of such here—viz., the end of the eccentric hoop or tenon into which the eccentric rod will have to be fitted (Fig. 96, *e f*). It can be turned, indeed, between centres, but a better plan is to drill and tap the end into which the rod is to be screwed, and mount it on a screw chuck of the same gauge. The shoulder, *e f*, can thus be turned very easily. The back centre can be brought up at the opposite side of the hoop as a temporary support, but this will hardly be necessary, as the part to be turned is so close to the chuck and so small. It is quite possible, when the hoop is thus mounted with the back centre to help support it, to turn up the edge to a rounded form, missing the lugs when the tool comes near them. But it is rather ticklish work, and needs a steady hand and light cut, and it is better to finish the part as already described. You can scrape it up when on a mandril by taking hold of the lathe cord to enable you to stop at the lugs, but chipping or filing is preferable.

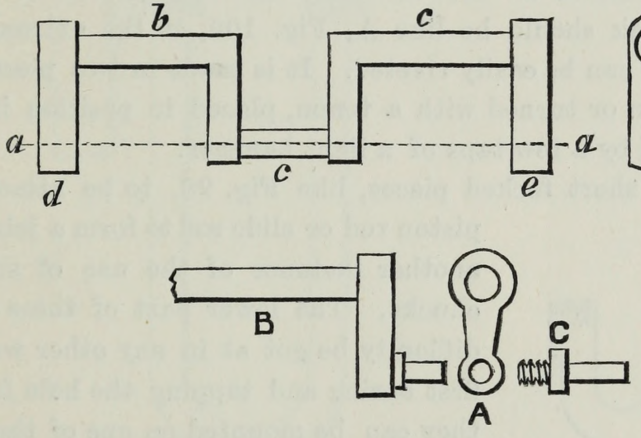


Fig. 97.—Crank Turning.

With the cranks it is not absolutely necessary to turn up the pin upon which the connecting rod works, but there is no great difficulty in so doing. Of course, if the crank pin is at the end, outside the standard, it can be turned separately and screwed in and riveted, but sometimes the crank is formed in the middle of the axle, to which it is eccentric, and we must then contrive means so to centre the axle in the lathe that its crank pin may be in the centre line of the mandril. Fig. 97 shows a very common way of doing this: B, C, is the axle first turned between centres at *b* and *c*, missing the crank. Two pieces of iron (*a*) are then keyed temporarily on the ends, and in these centres are punched or drilled in the line *a a*, which, it will be seen, is the centre line of the crank pin (*e*), which now, therefore, will run true in the lathe, and can be turned.

It is evident that the ends of such an axle may be bent down in lieu of attaching these pieces, and these ends can easily be cut off after the crank pin has been turned true. This is a much quicker method than the first, which is, however, almost necessary when the axle is of large size. It will probably be rightly conjectured that the axle or crank will be liable to yield, and so escape from the centres, to the detriment of the work. To prevent this, blocks are generally placed between the sides of the cranks and the attached end pieces. These, of course, take the thrust as if the whole were one solid bar. Few crank pins of model engines are turned, but they look much better, as nice shoulders are thus made at the ends of the crank pin ; but mere bent wire, such as forms the axle of many model engines, does not admit of this finish, nor does it require it. Wherever it can be done, and this is the case in most engines, the crank should be like A, Fig. 100, at the extremity of the axle, to which it can be easily riveted. It is made in two pieces, the pin being screwed in or turned with a tenon, placed in position in a drilled hole, and riveted by a few taps of a light hammer.

In fitting up short forked pieces, like Fig. 98, to be attached to the piston rod or slide rod to form a joint, we have another instance of the use of small screw chucks. The lower part of these could with difficulty be got at in any other way, but by first boring and tapping the hole for the rod, they can be mounted on one of these chucks and turned easily enough. The long fork, Fig. 98, seldom needs turning, but if there is a boss, which would look better, it can be held in a similar way. Also for polishing or finishing the heads of screws the hollow screw chuck is very convenient, as the little screw is thereby secured at once very truly while its head is entirely exposed to the action of the turning tool. Knucklejoints, like those of the forked connecting rod shown on a larger scale in Fig. 99, can be shaped on the outside to a great extent by grinding on an emery wheel running between centres in the lathe. A bar is turned to go easily into the pin holes of the fork. It has a squared end, which can be held in the tool holder of the slide rest, either vertically or horizontally. The

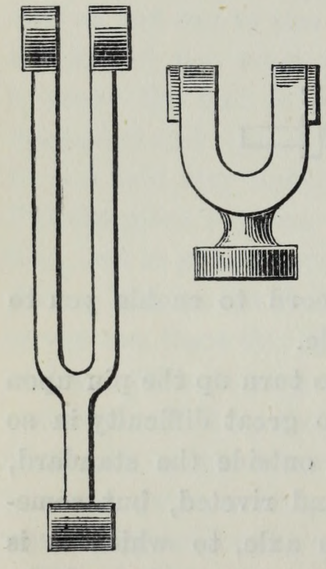


FIG. 98.—FORKED CONNECTING ROD.

fork being held on, this is turned about while the revolving wheel is allowed to grind it as it is swept backwards and forwards upon its bar. By first holding the fork horizontally and grinding as far as can be reached, and then placing the bar so as to hold it vertically, the greater part can be got at, leaving only the angle for the file to work upon. At A the wheel and the joint are seen in profile, the bar on which it is pivoted being omitted for the sake of clearness. The outside of the joint can evidently be got at until the arm of the fork is in one of the two positions shown by the dotted lines, and as the centre upon which the joint rotates during the process is fixed, it is plain that the outside will be made truly concentric with the hole through which the pin will pass, which connects this fork with the end of the piston rod. There is a similar knuckle joint at the opposite end of the fork, and on one or two other pieces, which can, of course, be finished in the same way.

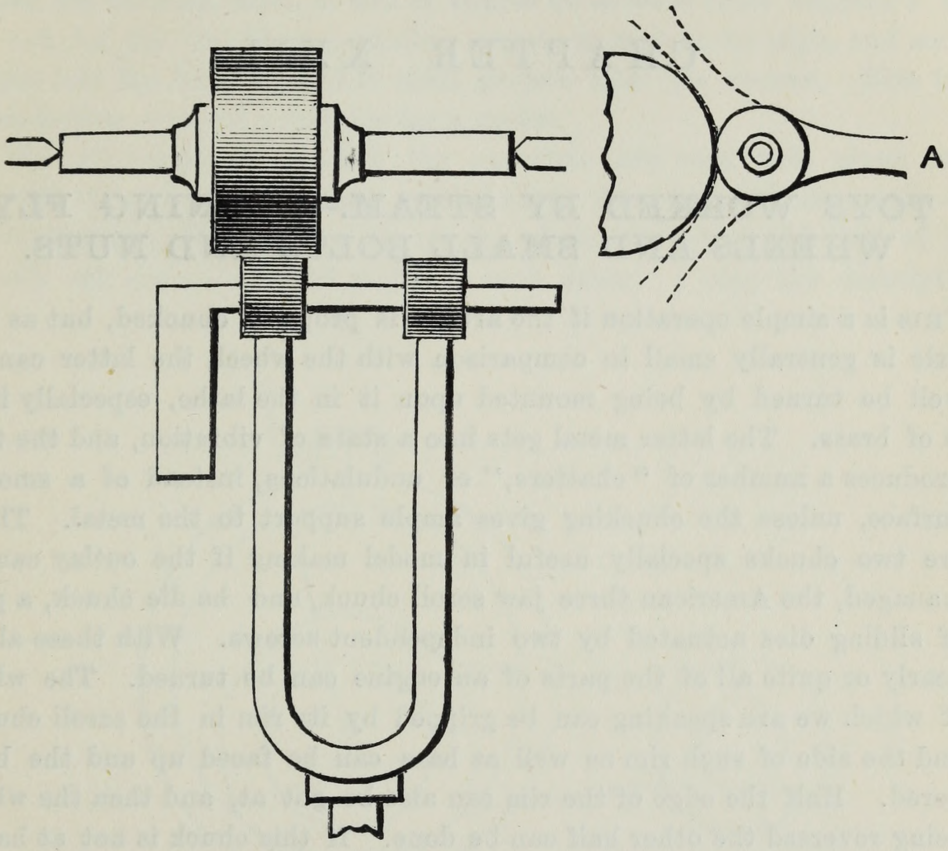


FIG. 99.—SHAPING BOSSES (SHOWING FORKED CONNECTING ROD).

CHAPTER XXII.

TOYS WORKED BY STEAM.—TURNING FLY WHEELS AND SMALL BOLTS AND NUTS.

This is a simple operation if the article is properly chucked, but as the axle is generally small in comparison with the wheel, the latter cannot well be turned by being mounted upon it in the lathe, especially if it is of brass. The latter metal gets into a state of vibration, and the tool produces a number of "chatters," or undulations, instead of a smooth surface, unless the chucking gives ample support to the metal. There are two chucks specially useful in model making if the outlay can be managed, the American three jaw scroll chuck, and he die chuck, a pair of sliding dies actuated by two independent screws. With these alone nearly or quite all of the parts of an engine can be turned. The wheel of which we are speaking can be gripped by its rim in the scroll chuck, and the side of such rim as well as base can be faced up and the boss bored. Half the edge of the rim can also be got at, and then the wheel being reversed the other half can be done. If this chuck is not at hand, drive into a boxwood chuck, face up one side, reverse in a new chuck, and turn the other. Having thus got off all the hard skin and made the wheel fairly true, it can be mounted on a truly turned spindle or arbor chuck, and gone over with a very light cut to finish it and make it run perfectly true upon its own axle.

You will nearly always find it necessary to chuck such a wheel by its rim in the first place, or, if it be an iron one, by laying it on a face plate and securing it by bolts and clamps by its spokes, and then the edge and face can be got at both of the rim and boss. But in this case, as in the other, you will probably need three cuts—*i.e.*, after mounting it, turn one side flat, reverse, and bed down upon this and turn the other side, then mount on its own spindle, or upon a truly turned arbor, and take a very light cut all over it. It will by this means run true. But with small brass wheels the spokes are often too light to be so utilised without danger of fracture or bending, and a cup chuck or scroll chuck becomes necessary. The latter involves an outlay of two sovereigns, perhaps, but it will save its cost by economising time.

The eccentric strap of which I have already spoken must be prevented from slipping off the disc. If this is made with flanges, so that the strap fits between them, it will of course be secured from slipping ; but if not, let the disc have a shallow groove turned in its edge, and screw a pin into the strap so that it shall project into the groove. This is a simple plan, and very suitable for a model.

The directions for setting the eccentric are very well given in a mechanical work by Watson, published in America, and he points out that the long diameter, so to speak, of the eccentric and that of the crank are always at right angles to each other. I copy the description

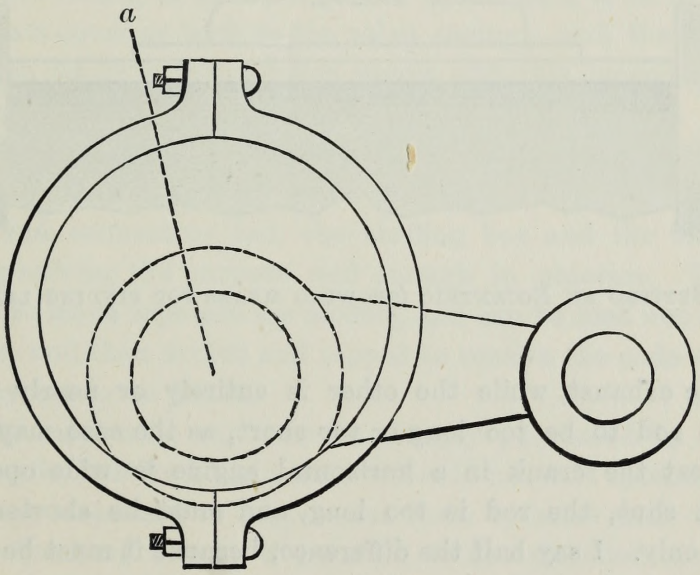


FIG. 100.—SETTING AN ECCENTRIC.

and drawing (Fig. 100), as it can hardly be improved upon, and it also gives the means of finding the proper length of the eccentric rod. The latter, in a model, is screwed into the strap, and, if desired, it can also be made with a screw at the valve end with two nuts, one of which will lie on each side of the boss on the back of the slide valve, as in Fig. 101 (A), where C C are the nuts and B the screwed rod, which must, as explained, pass quite freely through the boss of the valve, so as not to tie it in the least. By thus screwing the rod at one or both ends its length can be perfectly adjusted.

To find the length of the rod, put the straps on the eccentric and connect the valve gear as in working order. (The back of the valve casing must be taken off so that the slide can be seen as it works, and if this casing is in one piece, with no separate back, so that there is no stuffing box and no guide, a temporary guide must be made by soldering on a bit of tin shaped to form one.) Disconnect the engine, and slip the eccentric round on the shaft, and observe what takes place in the valve box. The eccentric is as yet not keyed on the shaft, and, if turned round, will have the same effect on the valve as it would if fixed on the shaft and turning with it. Doubtless the valve will uncover one port clear to the exhaust, while the other is entirely or nearly shut. This shows the rod to be too long or too short, as the case may be. If the port nearest the crank in a horizontal engine is wide open, and the other port shut, the rod is too long, and must be shortened half the difference only. I say half the difference, because it must be remembered that what is taken off one end is put on the other. When the valve "runs square," as it is called, or opens and shuts the ports properly, set the eccentric, as shown in Fig. 100, p. 211. The eccentric is always in this position in every case, whether the engine be vertical, horizontal, or inclined. The wide part of the eccentric and the crank are always at right angles to each other, excepting such departure from a right angle as the lead and lap takes off. Fig. 100 represents an eccentric without lead, working a valve without lap. (This will suit a model.) Such a coincidence seldom obtains in practice, and the true position of the eccentric is shown by the dotted line, *a*. This indicates that the eccentric is turned on the shaft a little away from the crank, thus pulling open

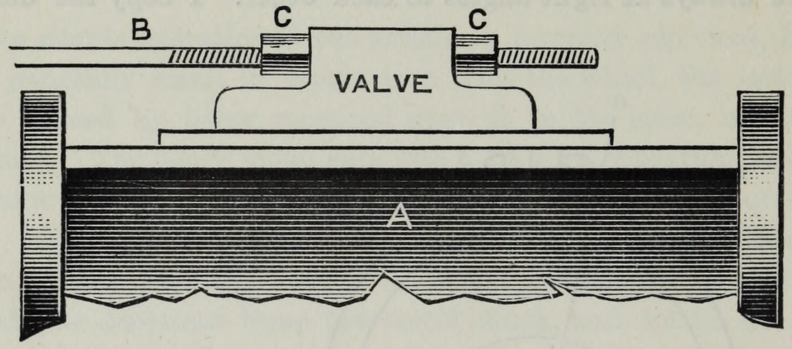


Fig. 101.—Setting an Eccentric (showing means for finding length of rod).

the port in front, and driving the crank in the right direction. It will be easily understood why the eccentric is always in this position, when it is borne in mind that the eccentric must commence to open the valve a little before the crank gets to the centre; in other words, the eccentric must commence its stroke a little ahead of the crank.

It will be seen from the above directions how much more convenient it is to have the steam chest or valve casing made as a box without top or bottom, and to have the back separate. In this way, at any time, the latter can be taken off, and the action of the valve seen. If the sides and back, on the other hand, are a single casting, and it is desired to examine the valve for some defect in the working of the engine, it becomes necessary to clamp on a guide of some sort to keep the valve in position as it slides to and fro over the port faces. This is not of any great importance in a very small model, where it is advantageous to have as few pieces as possible to connect together in building up the engine; but in a larger model, or in an engine of useful size, it is far better to have a separate cover or back to the valve casing; and the same bolts which hold the casing to the cylinder secure also this loose back, so that there is no more trouble in putting it together.

It will be necessary to have a hinge or knuckle joint between the valve rod and eccentric rod, but no guide is required here, as it is with the piston rod and connecting rod, the stuffing box and the inside of the valve casing serving the purpose well enough in practice. These joint pieces are best made separate for models, and can be filed out of suitable bits of brass, and then drilled and tapped to receive the ends of the rods to which they are to be joined.

Small bolts and nuts can now be cheaply purchased by the dozen, beautifully made, but the bought ones often do not suit special cases, and then it becomes necessary to supplement them by home made ones. For this purpose the best way is, if possible, to use six-sided steel wire or steel bar, as the bolt heads and nuts are then ready shaped, and the difficulty of forming them by filing is thus escaped. But this steel is not always at hand. It is, however, well worth keeping in stock for the purpose of making small punches, chisels, turnscrews, and other articles, and in that case any bit of round bar of iron or steel must of necessity be substituted. For such a job as this the die chuck or grip chuck is of great service; or, in default of these, a small bell chuck, with six or eight stout gripping screws. This chuck is often badly planned. It should be very thick in proportion to its size, and the screws should be of steel, with squared heads, to which a good steel key with cross handle should be fitted. The holes for the screws should then be recessed by means of a pin drill or cylindrical countersink, so that in a general way the screw heads hardly project above the general surface of the chuck. A very useful chuck of this class is one made of steel, and 3in. in diameter, bored to 1in., leaving, therefore, an inch thickness of metal. The holes should be countersunk to ½in., leaving a screwed portion of ½in. The screws when quite down to the centre, or all touching, should just bed down with the underside of their heads resting on the metal at the bottom of the recessed holes. Allowing ¼in. of length for the squared heads, therefore these should never project more than about that distance, even when a bit of stuff of the full diameter that the chuck will take is being worked. Made thus, there is also no fear of splitting or bursting the chuck, though the feat is easily accomplished with one of cast iron when not sufficiently thick, as the strain is very great. If cast iron be used it will be better to have forged rings shrunk on the outside to prevent this liability to burst.

In making a screw bolt, grip a bar of iron or steel in one of the chucks named, and reduce it with a graver to the size required—a very simple job if the graver is in condition to cut as it ought to do. Let the rest be as close as possible to give proper support to the tool, and take care to hold it steadily. Should the screw be so long as to need the support of the back centre, make a centre at the end with the point of the graver as it revolves, and bring up the poppit. You *must* make this hollow centre after mounting it, but if you want it deeper, begin it with a graver to get the position correct, and you can then deepen it by holding a drill against it. But you may easily turn down a bar of iron or steel—especially the latter—of ½in. diameter, and projecting 2in. from the chuck without the back poppit, and reduce an inch or more to a diameter of ¼in., or less, if you use the graver deftly: the grip chucks are specially intended for such work. Turn the bar, then, to the required size, and proceed to screw it by means of a screw plate or die stock, if it be too small to chase safely with a comb or screw tool.

The best screw will be made by stock and die. There are some very neat and light German or Swiss screw stocks with split dies, and made with finer threads than the Whitworth standard, which do this kind of work capitally. There is no need to remove the work from the chuck or the chuck from the lathe mandril, but the latter may be done if it is thought more convenient. Having cut the thread (and in doing it take care not to bend or twist the screw, which is but too easily done with a common screw plate), proceed to turn the head, and then cut it quite or nearly off with the graver, taking care to leave the right hand side of the neck or notch thus made quite flat, as it will of course be the top of the screw head. If you have a division plate to the lathe you will now, as in so many other instances, find it of service, because when you have turned up the screw head you can mark it with six lines to guide you in subsequently shaping it as a hexagon.

But if this convenience is not at hand you may finish cutting off the screw, and then hold it in the vice in copper or lead clamps while you file up the sides of the head. This is always considered a difficult job to execute satisfactorily, but will be facilitated by the use of a nut gauge —a notch of 120deg. angle, filed in a bit of sheet steel or tin. This will be the angle of each angle of a six-sided nut or bolt head. Another reminder is that each side will equal in length the radius of the circle of the head. Suppose, for instance, the head is ½in. diameter it will be ¼in. radius, and each of the six sides will be the same. File a flat, therefore, to begin with, till its length is ¼in. or a little less to allow of finishing with a fine file. Then take the nut gauge and, laying it on the bolt head with one edge just over the flat already filed, scratch a line by the other edge for the second face, and proceed to file this, testing it for length and angle, and thus go round the entire six sides of the head. It is advisable to make a few bolts and nuts, with heads ¾in. or 1in. diameter, before constructing the very small ones used for models, as this gets the toymaker accustomed to the work. Simple as it seems, this is not work in which success is to be expected in a first trial, especially if a bolt head is not more, perhaps, than ¼in. or ⅜in. diameter. Hence it is better to procure for the purpose six sided bar and wire, and to turn down the part needed for the stem and screwed part of the bolt.

You must, of necessity, make the bolts singly, but can generally manage to chuck sufficient length for two at least, so as to enable a second, or even a third, to be turned after the first has been removed; but with nuts the case is different. You can drill a length of rod sufficient for two or three, and tap it, and then file up the six faces before cutting any of them off. The best way is to mount the stuff as before, drill and tap it while still in the chuck, and then notch it deeply with a graver at equal distances. Then, if you have a division plate, mark the six lines, ruling them along the T of the rest placed level with the line of centres, and next either saw off and file up each separately, or at once file up the faces and saw them off, afterwards mounting each on a screw chuck of suitable size and thread to turn up the faces truly. In large establishments the six faces are cut on a special milling machine, a lot of nuts being placed upon a spindle side by side, and made to traverse under the cutter as it revolves. The machine has its own dividing plate, so that there is no practical difficulty in getting the sides and angles correct.

Nicely finished nuts and bolt heads contribute not a little to the smart and workmanlike appearance of an engine or other model, though amateurs generally make them very carelessly, as if they were of no great importance so long as they held the work together firmly. Even this, however, they will fail to do if the faces of both are not flat and true, as the bearing will otherwise be but partial. For this reason both sides of every nut should be turned in the lathe to render them perfectly parallel, and the holes in the parts of the engine which are to be secured by such bolts should always be sufficiently large to allow a little play.

* * *

CHAPTER XXIII.

TOYS WORKED BY STEAM.—LOCOMOTIVE ENGINES.

HAVING detailed the construction of stationary engines and the various fittings, we will now treat of the locomotive. There is no very great difference between the two, most of the parts being common to both. But in a locomotive we are, in reality, using a pair of engines worked by one boiler, each being complete with its cylinder and slide valve, eccentrics, connecting rods, and reversing gear. The multi-tubular boiler is, however, essentially a locomotive boiler, and, of course, the arrangements of the parts are, in a great measure, peculiar to the special type of engine. Such engine is, however, easily convertible to the kind of work a stationary engine is wont to perform.

In the simplest form of locomotive we can dispense with everything but the boiler and the cylinder, or cylinders, if the latter be of the oscillating kind of single or double action. Some catalogues advertise these with one such cylinder only, but they are not really worth buying or making, and we need condescend to nothing less than a pair of single action cylinders to drive the little locomotive. To commence with the boiler. This will be made of tin or of brass tubing, the latter being, of course, preferable for strength as well as appearance. In the little book called "Engines, How to Make, Buy, and Use Them," there is a drawing and description of a locomotive boiler made of brass tube, the under part being cut away at the bottom, and a flat piece soldered in above the lamp. Though this somewhat destroys the symmetry of the tube, it is the best plan if brass be used; but if the boiler is made of tin or of copper, it is, of course, easy to give it a flat, arched, or corrugated bottom, the object of the latter being to increase in the simplest manner the heating surface; for it may be remarked that the general difficulty is to keep up a sufficient supply of steam without raising the wicks of the lamp unduly high, the result of which is an overflow of spirits of wine or naphtha—a great mess on the table, with some risk of producing a disastrous conflagration, and the disruption of the boiler by melting the solder.

It may be as well, perhaps, to sketch a few boilers suitable for small locomotives before going further, if only to show how much scope there is for ingenious adaptation of a few simple expedients to the desired end, which is to give as much heating surface as possible, so as to make the most of the sources of heat at our disposal. Fig. 102 (A) shows a cross section of a boiler of strong tin plate. The upper part is merely a straight strip bent to a semi-circular form, and turned out at the lower edges $\frac{1}{16}$in. This is for the purpose of attachment to the footplate or frame of the engine, as well as to give a good bed to the solder. The bottom is a narrower plate similarly bent, and the edge turned out a little wider, say, $\frac{1}{4}$in. The same figure at B shows the two parts together, and it will be seen by the lines representing the water how the latter is divided on each side into comparatively thin layers, and how much is exposed to this lower plate, under which the flames of the lamp are to play. The dotted line of A shows the plate turned out $\frac{1}{16}$in. all round to receive the flat end of the boiler, but if preferred, this may be turned up

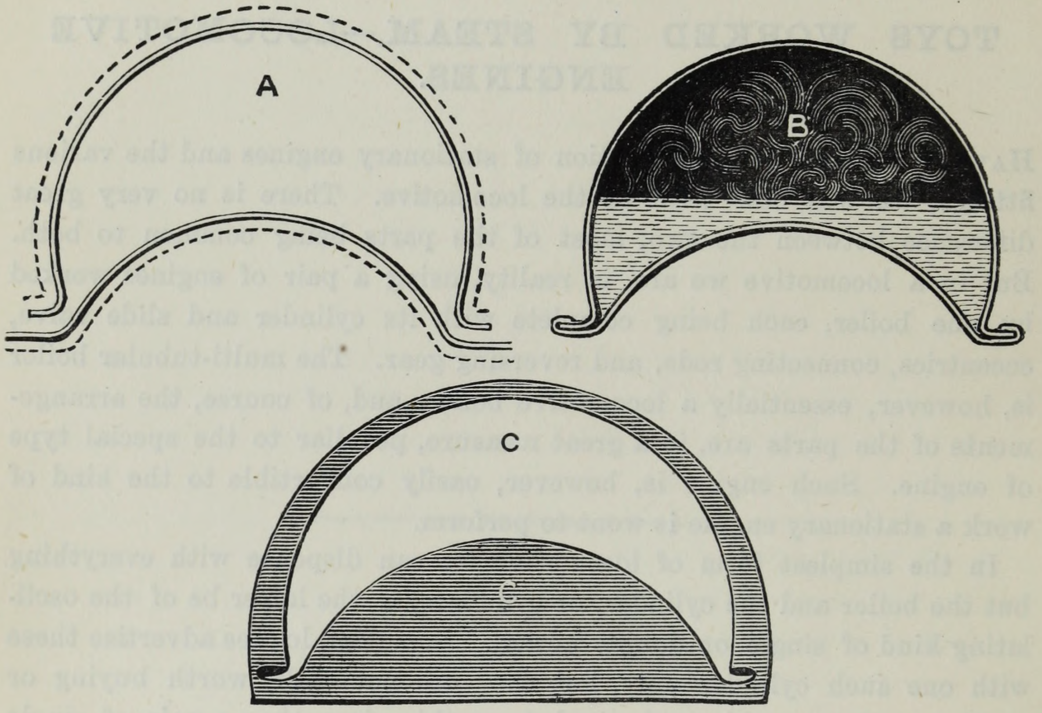


Fig. 102.—Tin Boiler for Engine.

instead to embrace the tube. The joint will be all the neater and stronger thereby.

To solder the long seams so as to give the utmost strength, they should have a thin layer of solder carried along the faces that will be in contact before the two are put together. Then, if placed in position, and a well heated iron carried along upon the upper one the solder will be melted, and the whole breadth ($\frac{1}{16}$in.) be soldered. The additional $\frac{1}{16}$in. of the lower plate can then be turned up over the joint and neatly laid down by the hammer. This seam no amount of steam pressure can rend asunder. But at the same time we must remember that the strength of a boiler is the strength of its weakest part, and not of its strongest, and we shall not make quite so satisfactory a job probably of the attachment of the ends, owing to the peculiar shape of the cross section. We must do the best we can, however, in fitting on these two crescent-shaped pieces. On the whole, it will be as well *not* to make these the counterpart of the ends of the already soldered tubes, but to make them semicircular, and to bend out the tubes all round to about $\frac{1}{16}$in. Then, having tinned this bit, which has been so turned out, lay it on the semi-circular plate, the curved part of which is made to match the curve of the upper part of the tube, and solder it on securely.

It will be as shown by C in Fig. 102, where the shoulder part is, the semicircular end coming, of course, a little below the crescent-shaped tube. Then in the end nearest the lamp (*i.e.*, the hinder one) cut out a place to allow the tube of the wickholder to pass it if found necessary; but the wicks should not touch the boiler, or the flames will lose power. The semi-circular ends will have a better appearance than if crescent-shaped, otherwise it is not of much importance which form is adopted. But there is one way by which you can get a folded joint as well. Cut out a crescent to overlap a little the turned-out ends of the tube, and bend it up all round so that the tube fit nicely just inside it. Then, when well fitted, tin as before, solder, and hammer down all round. You will do this more easily if, with a pair of flat nosed pliers, you first bend over the tin little by little. This done, cut out a pair of semi-circular plates, and with just a touch of solder here and there solder them on outside these crescent-shaped ones. Neatly done, they will be almost like a single plate, but you will have gained the advantage of a good folded seam to the boiler.

Tinplate work is simple, but it needs a little practice to make nice joints. One hint I may give on this point is, never to use too much solder, it should be a mere thin film, so that the plates may come as nearly into contact as possible; a thick layer is not only clumsy in appearance, but defeats its own object by keeping the parts asunder which ought to be united. The funnel, which will, of course, be added subsequently, has no connection with the lamp chamber or with the inside of the boiler. It is, in this case, added for appearance sake, but is essentially a make-believe, of no use whatever.

Let us now pass to boiler No. 2, in which we shall improve matters in this last respect, and in some others also. A longitudinal section appears in Fig. 103. We have here a round tube or cylinder of tin, brass, or copper, but there is now an additional inclined tube inside it, which is preferably conical, the larger end below just over the biggest wick of the lamp. This tube ends at the base of the funnel, which will carry off the smoke, if any, and the heat of the lamp will now become chiefly concentrated in the inside tube. Other wicks can, however, still be added if the first prove insufficient, but as the flame may now be of good size, one wick will, in all probability, answer the purpose. This boiler, whether of tin or brass, is not more difficult to make than the one last described, but is a fitter arrangement for one of larger size than contemplated in the previous description. Of stout tin, it will be found a very good pattern up to 6in. long by 3in. diameter, and should keep a pair of cylinders of $\frac{3}{4}$in. bore and $1\frac{1}{2}$in. stroke at work without any difficulty.

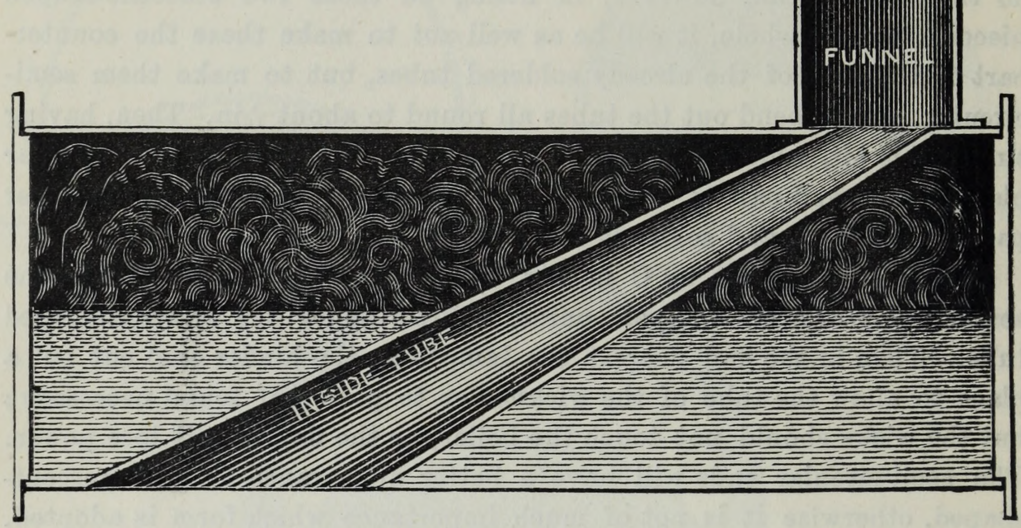


FIG. 103.—BOILER WITH INSIDE TUBE.

The next drawing (Fig. 104) shows two such tubes, each over its own lamp wick. We do not have two funnels, but the wick nearest the lamp can have the fumes which escape from it carried off by the little perforated cap *B*, which will stand as a man-hole or lock-up safety valve, and will not, therefore, appear out of place or unsightly. A boiler like this with two tubes will keep up a good amount of steam, and here again no difficulty should arise in constructing it. This, however, will be best made of brass tube, and the materials should consist of a length of tube 2in., 3in., or 4in. in diameter and 3in., 4in., or 6in. in length, and two cast ends, which will require to be turned in the lathe. These are supplied by the shops to suit different sizes of tube, and in substance are about ⅛in. thick, so that gauge taps and similar fittings can be fitted by screwing them. Fig. 105, p. 222, shows such a disc in plan and section. It will be seen that it is made with a flange, which is to fit exactly inside the ends of the tube, so that with solder it can be well secured and made steam tight and strong. The more flange it has the better, and only sufficient thickness need remain to form a neat head, slightly larger than the tube, to give a nice finish. If well done, not a vestige of solder will appear on the outside, and the joint will be quite invisible. This is, consequently, far better than using tin, which has to be turned up and hammered over, and is not so easily manipulated, especially if the toymaker has not a good set of tinman's tools, and a fair share of practical knowledge as well. Moreover, by using brass we are enabled to screw in all the several fittings, even on the tubular part, if a fine tap be used to form the thread in the several holes, and if solder should be necessary

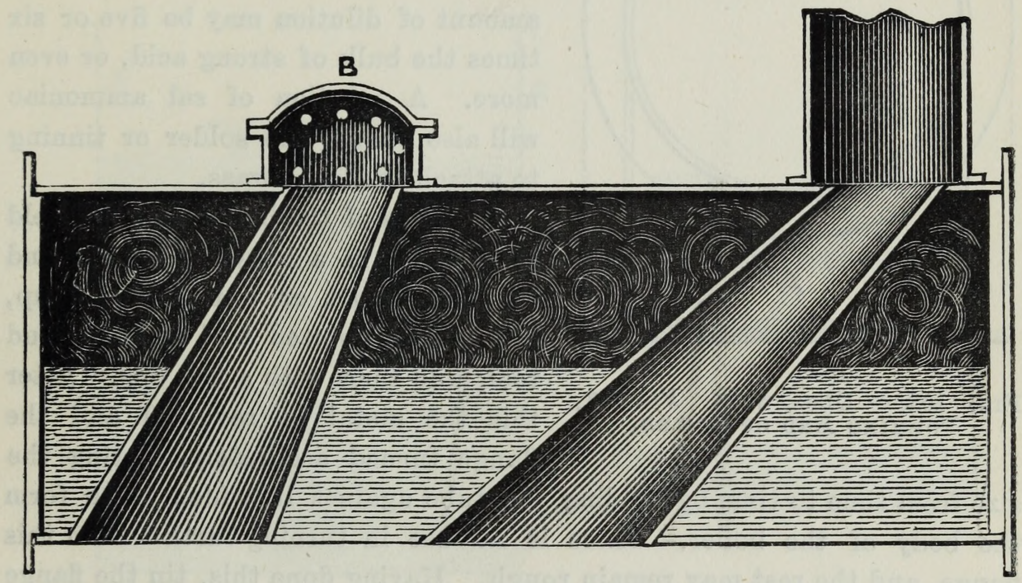


Fig. 104.—Boiler with Two Tubes.

at all, this is quite as easily used upon this material as upon tin plate, if the spot be first tinned by rubbing a little solder upon it, using as a flux either rosin or Baker's Fluid. The latter is probably much the same as a solution commonly used for work in zinc, which, indeed, will answer as well if the other cannot be had. Cut up a few bits of zinc plate, and drop one by one into a jar of hydrochloric acid (known as spirits of salts), continuing this till the acid will dissolve no more. Then dilute with water, and drop in one bit more of the zinc, which will most likely also be consumed in time, but insures saturation of the acid. The amount of dilution may be five or six times the bulk of strong acid, or even more. A solution of sal ammoniac will also enable the solder or tinning to attach to clean brass.

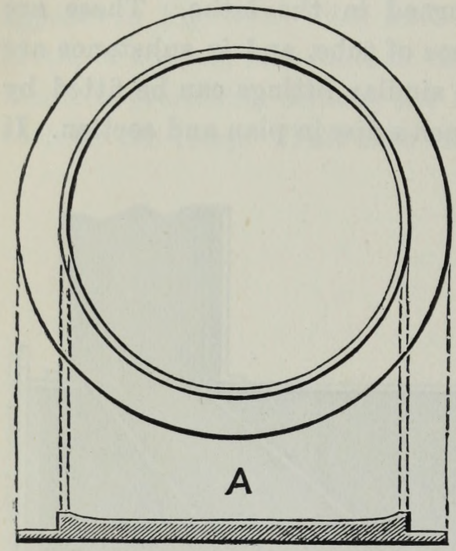


Fig. 105. — Disc with Flange, Forming End of Boiler.

The ends of the boiler may be held for turning in a boxwood chuck, and the larger part or outside faced up, first with a pointed tool or round-end tool, and then with a flat one. After this the metal is reversed and the flange turned accurately, testing the size from time to time by holding the tube against it, which is to form the body of the boiler. There is no use in turning further than this flange, and the rest may remain rough. Having done this, tin the flange and also the inside of the tube, using just so much solder that the one will barely enter the other when cold. Then, if the plate is laid flange uppermost on a piece of hot iron, such as the top of a kitchen stove, and the tube is placed in position and held by a woollen cloth to protect the hand, the tube will presently be able to be pressed down close on the flanged plate, the solder appearing, as it melts all round the joint, but in very small quantity, unless too much has been used. Slip a bit of tin or a knife under it to assist in lifting it, and set it aside for a minute or two on a cool surface, continuing to press it, and you will find a beautifully neat and strong joint, and the end will be quite securely fixed.

Boilers with a number of horizontal tubes, although superior in action to those previously described, are much more difficult to make, and almost too costly and troublesome for a toy locomotive, except only in cases where the real engine is to be very closely imitated. This class, however, belongs rather to models than toys. Such boilers require fire and smoke boxes at the ends beyond the part containing the tubes, and they can only be added safely by brazing or riveting.

After the two ends of the boiler (made as described of brass tube with a pair of flanged ends) have been neatly soldered on, the whole is generally mounted and turned in the lathe; but this will not be necessary if the flanges have been turned already, and the outsides also nicely faced over. If any solder appears it must be gently scraped off, and with finest emery cloth a good face can be put upon the whole by hand; then a leather, with a little fine dry sifted whiting, ought to finish the outside completely. But, left thus, it would very soon tarnish, and it should be warmed and a coat of lacquer applied thinly at once, which will preserve it from the oxydising influence of the air. The fittings of this boiler, such as safety valve, man hole (by which to fill it), gauge taps, and other usual accessories, need not be here detailed, as they have been minutely described already in treating of stationary engines. All those which are fitted to screw in will need a thin leather, lead, or copper washer, or a little red or white lead smeared over the parts which are to come in contact, and which are to be made steam-tight.

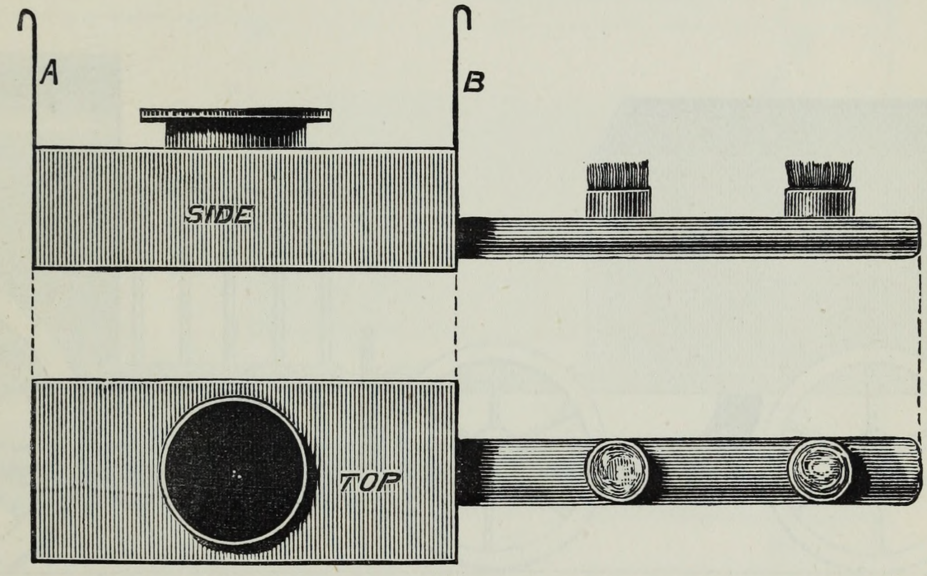


FIG. 106.—LAMP ARRANGEMENT FOR TOY LOCOMOTIVE SERVING AS FURNACE.

The lamp, which in this case is to serve as the furnace or fire, is generally made like Fig. 106, p. 223, a long tube from a reservoir being fitted with wick-holders at two or three places. It is suspended by means of two flat pieces of metal, A and B, which hang upon studs at the two ends of the boiler, the tube coming underneath the latter. When there is a tender—especially if this be made separate and attached by the usual link or chain to the engine—this may very well be made to fulfil its own proper office and to carry the fuel, being, in fact, the spirit reservoir. It is sketched here in Fig. 107 with a wick-holder attached. Being separate, the wicks can be got at for trimming, which would present a difficulty if the engine and tender were made in one piece. In all cases let the wicks be tightly packed into their respective tubes, as the spirit will then rise by capillary attraction fast enough to burn freely, but not to overflow.

Having decided upon the kind of boiler and lamp, the next consideration will be the framing which is to carry the boiler and support the wheels, and which is also used in toy locomotives to bear the cylinders with their steam blocks and fittings. These cylinders are, in the simpler models, generally placed at the wrong end—viz., close to the tender, or actually attached to it, when the latter is included in one frame with the engine, but this is merely for economy in arranging the steam pipe and for convenience, and so long as the little engine does not refuse to travel, the young owner of it is scarcely likely to quarrel with the maker for so arranging its details. The framing, if supplied from the shops, will consist of a base plate and a pair of side frames to attach to it by small screws, or of a base plate with a central cavity to receive the

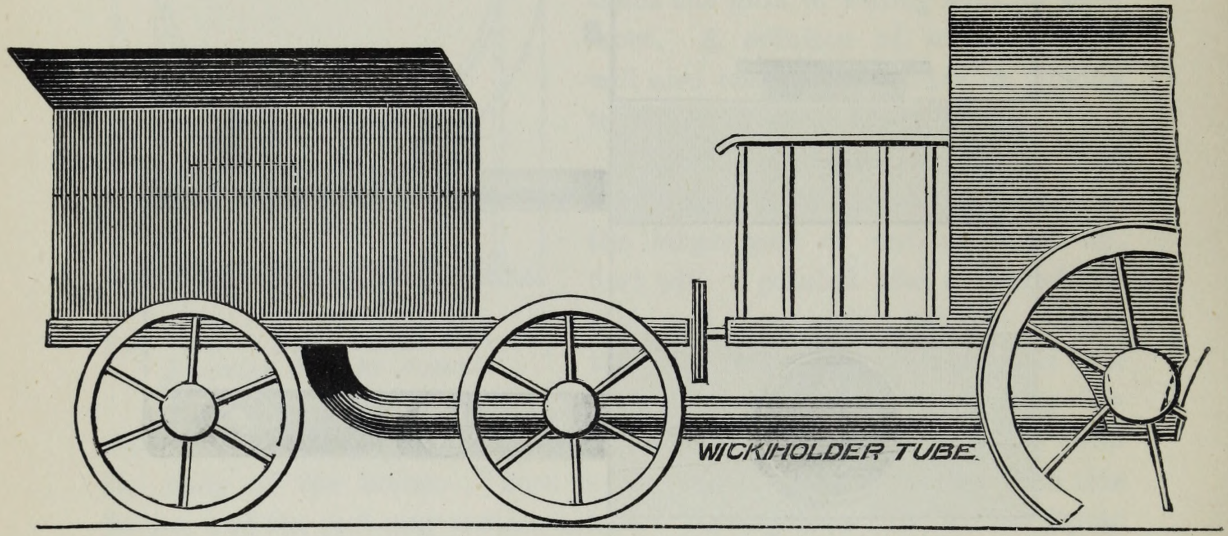

WICKHOLDER TUBE.

FIG. 107.—TENDER WITH WICK-HOLDER ATTACHED.

boiler and side and front frames in a single casting. It is generally possible with a little contrivance to find a homely substitute for this part, but castings are cheap. If a sheet of brass can be obtained $\frac{1}{16}$in. thick, you may build up a very good frame by bending down the two sides so as to form the side frames, like Fig. 108 (A). But to bend brass you have to anneal it by heating it red hot and then letting it cool slowly. You must not think you can bend it while red hot, as you would do if it were iron; for you would find it break off instantly. Let it cool, and it will bend easily, and after having bent it you can put it over a sharp edge, or hold it in a tail vice, and with gentle blows get a nice sharp bend, which, when further finished with a file, will not look like a bend at all, but have as good an appearance as if it were a properly made casting. It matters little whether you bend down in this way the sides or the ends of the plate; only, if you prefer the former, they must be marked out to

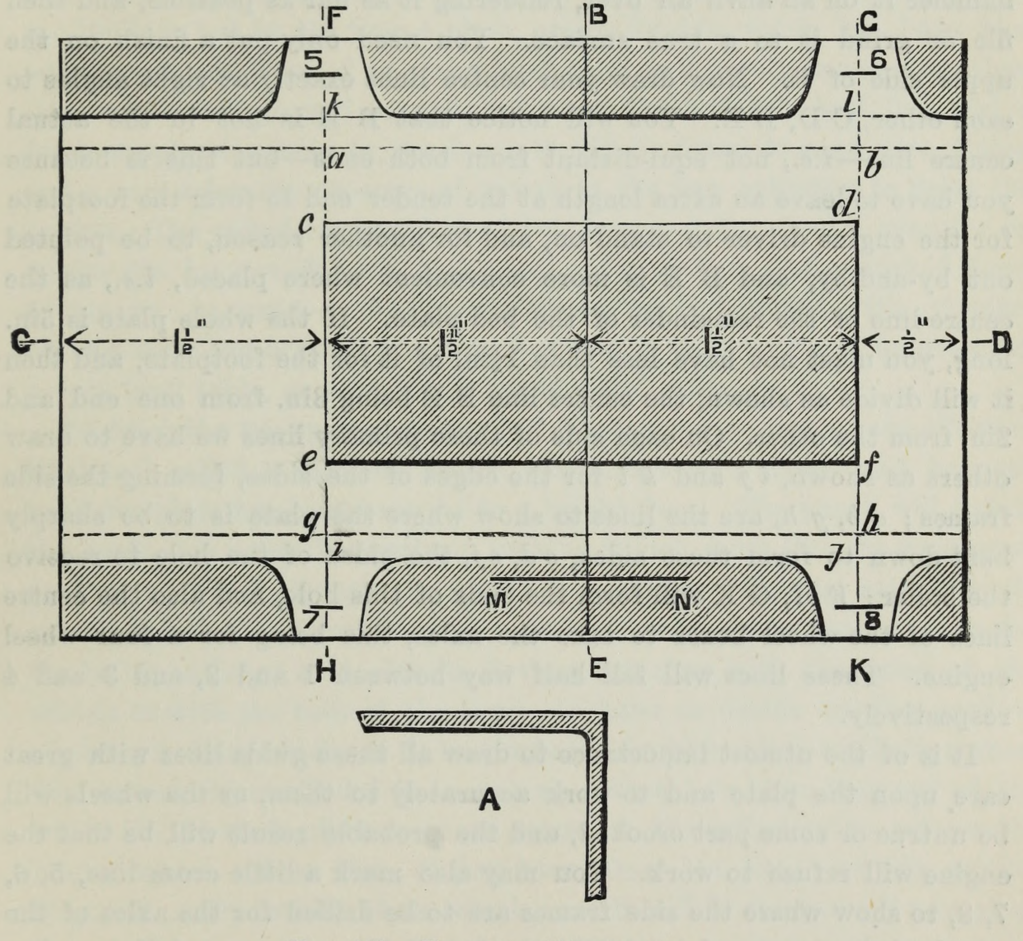


Fig. 108.—Framing (A) and Plate.

form bearings for the wheels, and be shaped accordingly. It is not absolutely necessary to bend down the ends at all, and a large number of engines have only the flat foundation plate with the two side frames, but the ends serve to fix buffers and give a more correct appearance to the toy.

The flat plate, before being thus bent, will have the form of Fig. 108. The shaded part is that to be cut away, the white part being the plate that will ultimately remain. Take the plate you design to use, and hammer it on an anvil all over, rendering it as flat as possible, and then file or grind it to a true surface. You need only put a finish on the upper side of it. Now draw your centre lines exactly at right angles to each other, C D, B E. You will notice that B E is not in the actual centre line—*i.e.*, not equi-distant from both ends—but this is because you have to leave an extra length at the tender end to form the footplate for the engine driver to stand on, and for another reason, to be pointed out by-and-by, and B E is more convenient where placed, *i.e.*, as the centre line of the remainder of the bed plate. If the whole plate is 5in. long, you must not have less than 1½in. of it for the footplate, and then it will divide as shown, the centre line B E being 3in. from one end and 2in. from the other. On each side of these primary lines we have to draw others as shown, *i j* and *k l* for the edges of the sides, forming the side frames; *a b*, *g h*, are the lines to show where the plate is to be sharply bent down to form these sides, *c d*, *e f*, the sides of the hole to receive the boiler; F H, G K will form the ends of this hole, and also the centre lines of the wheel boxes to take the axles, this being for a four wheel engine. These lines will fall half way between 1 and 2, and 3 and 4 respectively.

It is of the utmost importance to draw all these guide lines with great care upon the plate and to work accurately to them, or the wheels will be untrue or some part crooked, and the probable result will be that the engine will refuse to work. You may also mark a little cross line, 5, 6, 7, 8, to show where the side frames are to be drilled for the axles of the wheels, but you may have, perhaps, to test the accuracy of these after bending down the plate, as you may possibly spread or stretch it more on one side than the other. The hole for the boiler may be made by cutting with a sharp chisel or flat punch, or by drilling rows of holes and then cutting with a small saw or punch, the file being used to finish, and remember you will have to use a three square file to get into the corners. You will have a difficulty in bending nicely the part which is to form the side frames if you cut the latter first to the curve here delineated, because the plates are thus rendered so narrow. They should not be cut further than about M N before bending, so as to leave them sufficiently broad to bear the process easily, and a half round file will subsequently finish them to the required shape.

The plate should be as mentioned, $\frac{1}{16}$in. thick, to allow of sufficient filing after it is bent to get nice sharp edges, and you will hardly succeed with a lighter plate; and, if you are making an engine of larger size—over 6in.—a casting should be used, as providing a more satisfactory article to work upon. We have always, in these toys, to consider the weight, and to diminish it as much as possible, as our driving power is at best too limited, but by the time a plate, originally $\frac{1}{16}$in. thick, has been filed and ground and finished to a nice surface, it will hardly gauge more than $\frac{1}{20}$in., which will do well enough, but when the boiler is half full, and a fresh supply of spirits in the lamp, it will be found to need nice fitting and a very tolerable pressure of steam in the two cylinders to drive the engine. The cylinders should be of $\frac{1}{2}$in. bore and $\frac{3}{4}$in. stroke, even for an engine 4in. long, with a tin boiler and a foundation plate, worked down to $\frac{1}{20}$in. or $\frac{1}{24}$in. gauge. The 6in. engines are worked, indeed, with cylinders of this size, but are rather apt to hesitate in their progress unless upon a very level table, or upon nicely made metal rails.

To finish the top surface of the bed plate you can buy a very effective little tool called a matting punch, which, however, should not be used until the plate has been brought to a bright face. The punch will indent the surface in a regular pattern, making it look more like the roughened surface of the footplate of a real locomotive. Having satisfactorily accomplished this foundation plate, taking care not to cut the place for the boiler so large as to let its bottom interfere with the axles of the wheels or with the tube of the lamp, we have to decide on the position of the cylinders, which are to be single (or double) action oscillating ones. The second object alluded to in making a footplate $1\frac{1}{2}$in. long out of the whole 5in. of such plate is to get room for the cylinders to act on the hinder wheel. Even then, if you have them 1in. long and $\frac{3}{4}$in. stroke, they will partly overlap these wheels, and it will be the same if you place them in front or between the wheels. This necessitates a longer crank pin, and the steam blocks against which the cylinders work must be thick enough to place them clear of the wheel. These blocks are to be fixed to the side frames of the footplate, as far back as you can get them. For such an engine you can use wheels $1\frac{1}{2}$in. diameter or a little more, and the crank pin will have to be inserted in one of the spokes at a distance of $\frac{3}{8}$in. from the centre of the axle to give the $\frac{3}{4}$in. stroke. The two steam blocks which are to convey steam to the cylinders are connected by a straight tube passing under the footplate from one to the other, and from the middle of this, and forming a T with it, rises through the footplate the main pipe to the steam chamber of the boiler, into which it is made to enter as high as possible above the level of the water to avoid priming or getting water into the cylinder from the spray caused by ebullition. If the boiler has a steam dome above the general level of its cylindrical portion the steam pipe is turned up into this, so as to be still further removed from the water. The small engine, however, under consideration will probably not be made with a dome.

Although, in point of fact, the use of brass for the footplate and of brass tube for the boiler has been mentioned, a tin boiler and lamp is amply good enough for so small a toy, even if, for the sake of stiffness, the footplate is made of the first-named metal. This substance is light and cheap, and may be had of any degree of thickness that may be desirable. When japanned green or bronze colour it has, moreover, a sufficiently attractive appearance. The wheels are always of brass, as they require to be nicely turned in the lathe, and should be made with a flange or raised rim if meant to run on a line of railway. Moreover, when thus made they have a more decided locomotive look about them, and good looks count for something even in these days of education and science. The axles will be of wire and quite straight, and may be attached by solder, if necessary, after being inserted in a neatly drilled hole in the boss of the wheel. But here again an improved method is to tap the boss, cut a fine screw upon the wire, and screw the wheels on. Care, however, must be taken not to make a loose fit, but rather to file the ends of the wire axles slightly conical, so that they shall screw up very tightly. They can be very nicely adjusted in this way to run just clear of the frame, and yet to have no more play than absolutely necessary. It is not generally required to make such small axles with a shoulder at the bearings to prevent motion sideways, but if it appears desirable (and it is no doubt a safer plan), this can be easily done by careful filing, allowing the wire a size or two larger at the onset so as to permit of this reduction. For the pair of leading wheels, unconnected with the driving power, such precaution will certainly not be necessary. The only object of this extra work is to keep the driving wheels accurately in place, so as never even for a moment to touch the side frames.

The oscillating cylinder not requiring a slide valve or an eccentric, the toy maker will escape in the present instance the adjustments, which in a slide valve engine are apt to give trouble. There is, in fact, but one rod to adjust at all, namely, the piston rod, upon the end of which is screwed a little brass knob drilled through to fit upon the crank pin of the driving wheel, see A B, Fig. 109. The only chance of failure at this point, therefore, is from having the crank pin so far from the centre of the wheel that it jambs the piston against the ends of the cylinder. The whole stroke of the crank, it must be remembered, will be twice the distance of the pin from the centre of the wheel, and this must be always a trifle less than the whole travel of the piston, which is not actually to touch either end of its cylinder in its alternate movement. The directions given will suffice for the small engine, which, when complete, will be like Fig. 110. A separate tender for the lamp is not here used, but is a part of the engine itself.

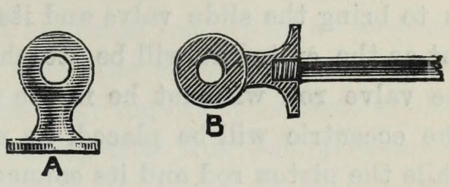


Fig. 109.—Piston Rod, with Drilled Knob.

Slide valve locomotives are more difficult to make, but a great part of the engine will be similar to that last described. As a superior toy, however, it will deserve a brass boiler with two tubes, or one with a single flue traversing it from end to end, to receive the wick-holder of the lamp, which should have two tubes rising at an angle, as shown in the drawings of boilers. The framing may consist, as before, of a base plate of brass, the side frames attached by small screws, as this plate may now be a little thicker, and will not be readily bent down

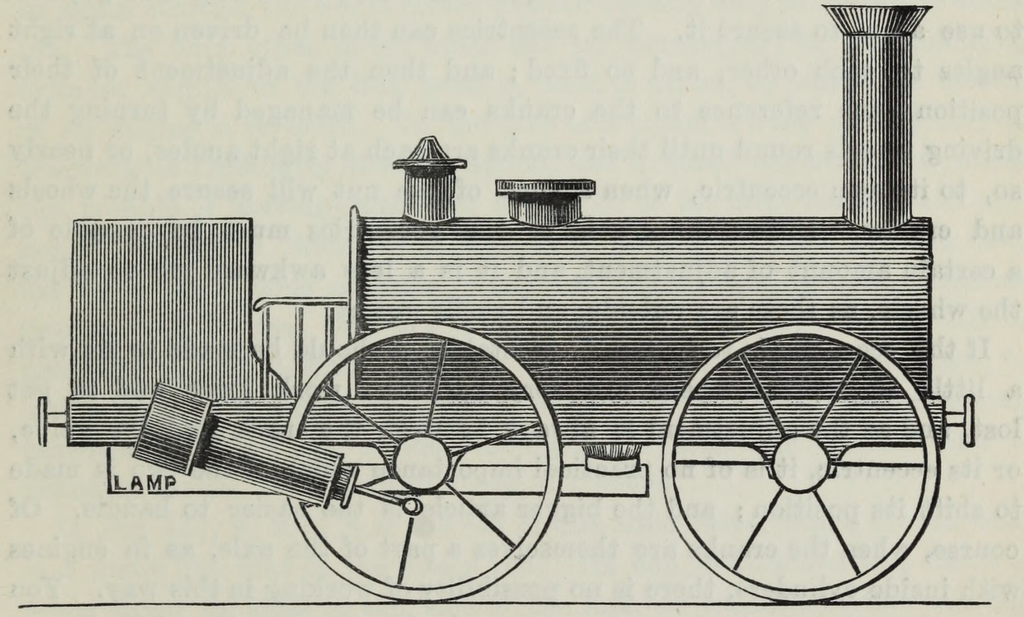


Fig. 110.—Complete Engine.

to form the bearings for the axles of the wheels. Small screws and suitable taps in handles are procurable at all model shops.

The cylinders will be made with a pair of small bosses or a flat piece on one side by which to attach them to the bed plate in such a position as to bring the slide valve and its casing on the inside next to the boiler, but as the cylinders will be attached to the under side of the bed plate, the valve rod will not be in the way of the boiler, but work quite free. The eccentric will be placed, as a rule, just inside the wheel bearings. while the piston rod and its connecting rod will be outside these and also outside the wheel. But the valve rod will be sufficiently far from the piston rod to permit this arrangement, and should there be any difficulty, owing to the driving wheel having too broad a rim, it is easy to bend the eccentric rod so as to keep it clear. All this is, however, provided for in the bought castings, which, when turned and finished, will be found to fit into place without entailing any of the suggested difficulties. It will be found, however, advantageous in fitting a slide valve locomotive to turn the axle of the driving wheels to a shoulder where the wheel is to go, and to use a nut to secure it. The eccentrics can then be driven on at right angles to each other, and so fixed; and then the adjustment of their position with reference to the cranks can be managed by turning the driving wheels round until their cranks are each at right angles, or nearly so, to its own eccentric, when a turn of the nut will secure the wheels and cranks. Either the cranks or the eccentrics must be capable of a certain amount of adjustment, and it is a less awkward job to adjust the wheels, as these are outside, and easily got at.

If the eccentric is to be itself adjustable, it should be made to fix with a little screw, but these are very liable to work loose and to get lost, and as the adjustment is always between the crank and the valve, or its eccentric, it is of no practical importance which of the two is made to shift its position; and the bigger article is the easier to handle. Of course, when the cranks are themselves a part of the axle, as in engines with inside cylinders, there is no possibility of working in this way. You must then of necessity have the power of adjusting the disc of the eccentric by turning it round on its axle until it is in the right position, but this need not be done when the crank is made by inserting a pin into one of the spokes of the driving wheel. But if the crank is not formed by a pin in the spoke, but is put on outside, this crank can be the adjustable part. All depends on the plan of the engine. The driving wheels of slide valve locomotives are generally larger in proportion than those made with oscillating cylinders, and a slot has to be made in the foundation plate to permit them to project through it. The wheel bearing will be just inside this. The piston rod guide, which is always necessary when the cylinder is fixed and a connecting rod leads to the crank, is generally a little brass eye screwing into the foundation plate, and the piston rod has fitted upon it a small block of brass, as shown in our drawing, into which is fixed the screw, which forms the pin of the connecting rod. The latter in the simpler models is merely a flat brass rod drilled at each end to fit on the screw just spoken of and upon the crank pin, which is, in fact, another screw. This connecting rod may require to be bent to clear the foundation plate and piston rod guide, but this will present no difficulty.

With eccentrics the toymaker should set them on in their places at right angles to each other. This is because the cranks are also to be so arranged, thus doing away practically with dead points, for one engine will be at full stroke when the other is at the dead points, and the power tending to drive the wheels will consequently be continuous. If both cranks were arranged to be in the same position an engine might chance to stop when both were on a dead point, and the engine could not be again started, the whole strain exerted tending only to break the crank pin. The only other detail which has no counterpart in an oscillating cylinder engine is the link motion, as it is called, by which the motion of an engine is reversed. In the case of a model it adds considerably to the work and difficulty of construction, and in small engines is not worth the trouble of making, although it may be so for large models, and cannot be omitted in those which profess to be miniatures of those in daily use upon our various railways. The use of four eccentrics is involved, two to each engine, and two links, with their fittings, such as will be presently described, with a common shaft leading from one to the other, by which a single reversing handle is made to act upon both links simultaneously. There are several modifications, but the slotted link is probably easiest to make and apply in a model.

In Fig. 111, p. 232, A is the rod of the slide valve, which should work in a guide like that of the piston rod. Its end is attached to a block of brass fitted to slide in the slot of the link, or rather to allow the link to slide up and down upon it. The link has two eyes or lugs, to which are linked by a hinge joint the ends of the eccentric rods, B and C (*i.e.*, of the two eccentrics belonging to either of the slide valves). Of these, one is the forward, the other the backward eccentric, and these are at right angles to each other as regards their "throw." In the position of the parts, as seen at A, the motion of the eccentrics communicated to their rods will have no effect upon the valve rod A, as the link itself will only move upon the end of A as a hinge or pivot. This is the position at the time the engine is still, or with no tendency to advance or retreat. But when the reversing handle or lever E, which is pivoted as shown, is pulled back or thrust forward, the bell crank turning with the shaft D as its centre, through the medium of the connecting rods, lifts or lowers the link until the end of the valve rod is in a line with one or other of the eccentric rods, which is thus in a position to act on the valve rod as if it were a part of it, the other eccentric rod then merely causing the free end of the link to oscillate. Thus, according as the forward or backward eccentric rod is brought in a line with that of the valve, it acts upon the latter, and the locomotive is made at pleasure to proceed in either direction.

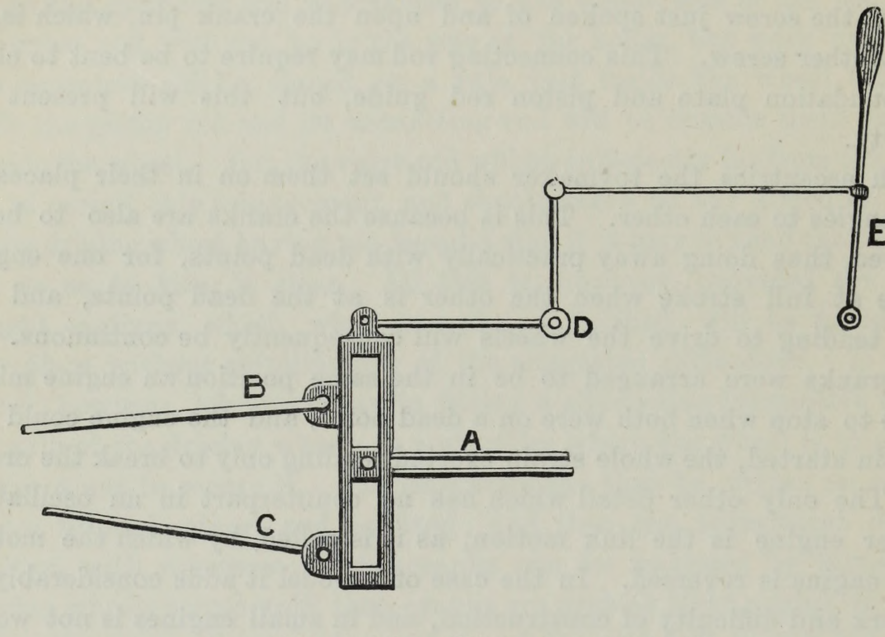


Fig. 111.—Slotted Link Arrangement.

The eccentric rods are arranged as regards length just as if no link was present, because it is evident that when either is brought to agree with the valve rod, it is practically a continuation of it, as it is when there is only a hinged joint and no reversing gear. The circle D represents the shaft which forms the fulcrum of the bell crank, and this is fitted in a pair of bearings carried by the base plate, the shaft passing across from side to side under the boiler. The links here illustrated are straight, and they will answer as well thus, but they are often curved, the radius being taken from the centre of the shaft of the crank axle.

At Fig. 112 a sketch is given of a slide valve locomotive complete. In a toy engine we can, of course, turn it upside down, and get at all parts

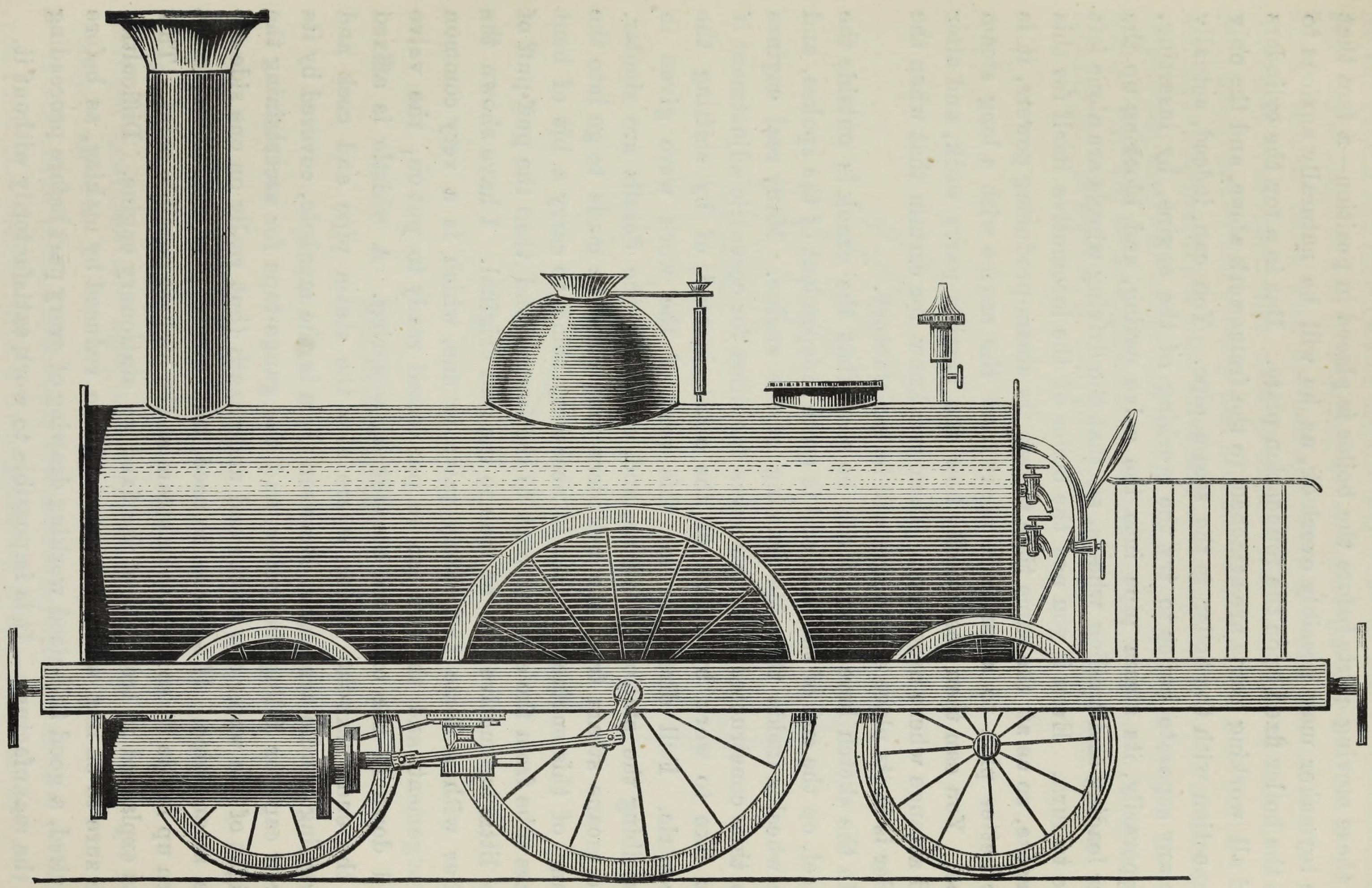


FIG. 112.—SLIDE VALVE LOCOMOTIVE.

underneath the boiler easily enough, but we can do more. We can adjust all these moving parts before the boiler is placed in position—a fact that the toymaker may possibly overlook, as he will be naturally anxious to get the boiler fixed upon the foundation plate. But in a toy the cylinders and all working parts are attached to the framework alone, and the only connection with the boiler is the steam pipe. You can, indeed, actually use any separate boiler to try the working of the engine, by inserting, temporarily, its steam pipe into the valve casing, and blocking up the four leading and trailing wheels, so that the driving wheels are alone left free to turn. Even if you use the boiler of the locomotive itself for this purpose, so as at the same time to test its steam-producing powers, it is the better plan to arrange it apart from the engine with a long steam pipe. You can then see exactly how the moving parts work, and alter and arrange where necessary. Then you know for certain that when the boiler is in its place everything will be satisfactory.

In the sketch here given it will be seen that the crank is outside the wheel, on the end of the axle, and is quite independent of the spokes, and the wheel is inside the side framing of the engine. Many real engines are thus constructed, and this gives facilities for eccentric adjustment if you like to work by means of the crank instead of by shifting the eccentric. Full directions for this part of the work were given in describing the stationary engine, and, of course, the details are similar. The escape steam from the cylinders may easily be made to go into the funnel of this engine, all that is necessary being to carry a bit of bent brass tube from the exhaust port to the funnel, and then the puff-puff of the little locomotive will be true to the real original. I have shown the boiler with a dome and safety valve in one, which is a very common arrangement, and the two can be purchased ready to put on, the valve held down in the orthodox manner by a spring. A whistle is affixed at the end next the tender, where also the steam pipe and cock and reversing handle are seen. Between them is the manhole, covered by its screw cap, for filling the boiler, and the gauge-taps for ascertaining the height of the water are at the end underneath (but really on one side of) the steam pipe. If a dome be used, this steam pipe, remember, must turn up inside it, so as to take steam at the highest possible point. This was explained in treating of the fixed or stationary engine. Difficulties are sure to be met with, but these will be reduced by making, as before advised, a good full-sized working drawing of every part before proceeding to the manufacture. It is impossible to work satisfactorily without it.

In the toy locomotive the several joints must work easily, so as not to increase friction unnecessarily, without, however, being actually loose.

No one should start locomotive engineering without making a model of the kind, on account of the nice fitting of so many parts, but should stick for a time to those with oscillating cylinders until the hand gets accustomed to the particular class of work. But when the first difficulties are passed, and model making has become tolerably easy, the better plan will be to commence the slide valve and reversing engine upon a tolerably large scale, say, with boiler 6in. or 8in. long, and cylinders of $\frac{5}{8}$in. to $\frac{3}{4}$in. bore. This will be an engine worth working at, and, when finished, worth looking at. Moreover, it will give less trouble in making, because the different parts will not be so small, and so difficult to finish satisfactorily on that account. We are not all born watchmakers, and the small models, if of a complete character, need watchmakers' tools, watchmakers' handiness and skill, and, not seldom, watchmakers' magnifying glasses too.

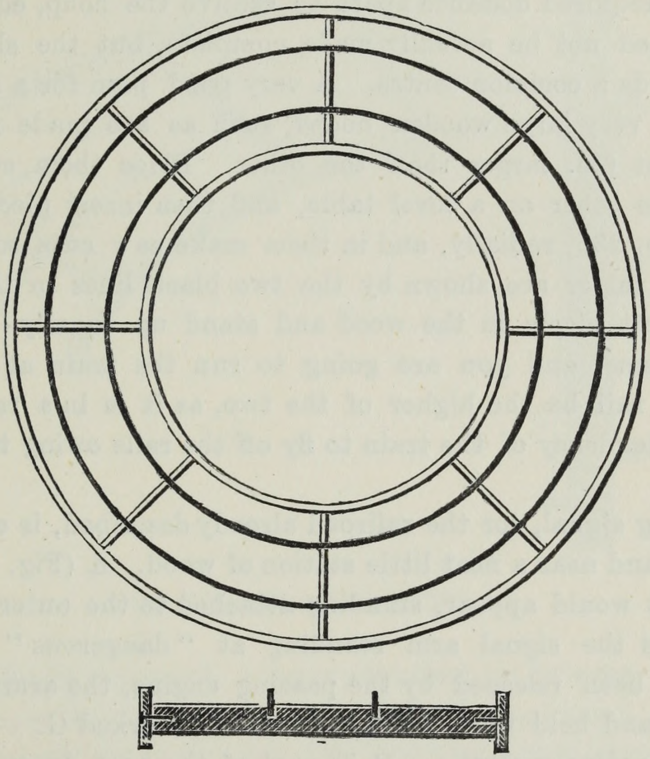


Fig. 113.—Diagram of Circular Railway.

It will not be necessary to carry locomotive toymaking further, so I shall conclude this chapter with a description of a circular railway, without which the engine department would hardly be complete. The advantage of a circular instead of a straight line of rails is that the engine can go ahead continuously, and does not need the reversing gear. It is not very satisfactory to have to start a locomotive upon the table or floor, and catch and carry it back, or turn it round every time it comes to its journey's end. A circular railway permits pace to increase *ad libitum*, and a very pretty sight it is to see a little model rushing along with its miniature carriages and trucks, without requiring momentary attention.

The rails consist of a strip of narrow iron hoop about as thick as clock spring—*thin* hoop, in fact, which you can get anywhere. The sleepers are, practically, the spokes of a big wheel in which saw cuts are made at the required distance apart to receive the hoop, edge upwards. The wheel need not be actually made complete, but the sleepers must radiate towards a common centre. A very good plan for a small engine is to get two very large wooden hoops, such as are made for children, but one about 6in. larger than the other. Place them concentrically one inside the other on a level table, and then insert pieces as shown at Fig. 113, p. 235, radially, and in them make saw cuts to receive the rails. These latter are shown by the two black lines in the drawings. They should fit nicely in the wood and stand up equally; or, if there is any difference, and you are going to run the train at high speed, let the outer rail be the higher of the two, as it is in a railway curve, to check the tendency of the train to fly off the rails owing to centrifugal force.

A self-acting signal, for the railroad already described, is easy to make, and should stand near a neat little station of wood. A (Fig. 114, p. 237), shows it as it would appear, standing attached to the outer hoop of the railway; C is the signal arm standing at "dangerous" or "stop." After having been released by the passing engine, the arm is raised to this position and held by an indiarubber cord, marked G. This may be the finest of ordinary elastic. B is part of the bent lever seen in the section on a larger scale at the second B, the signal post being double, made of two neat strips, kept apart and parallel by blocks (H) at top and bottom. When the arm of the signal is down it is caught by the hook at B, and the horizontal arm (E) of the bent lever comes just above the level of the rail, and, therefore, will be depressed as the wheels of the engine pass over it. By the depression of E the hook (B) is drawn away from the end of the arm (C), and instantly the latter flies out, owing to the elastic spring, and stands at danger. It has, of course, to be lowered by hand until again caught by the hook of the bent lever. It will be found much easier to let the arm be raised by a spring, because if it is done by a lever direct the latter will need more power to press it down, and it must be also depressed further to raise the signal to a horizontal position. Arranged as shown, the lever can be balanced so that the least touch will set it free, and the speed of the engine will not even be checked. If this and the whistle, however, are to be automatically managed, a lever standing up between the rails can be made to open the whistle and also turn off the steam, if long cock handles are brought down through slits in the bed plate of the engine.

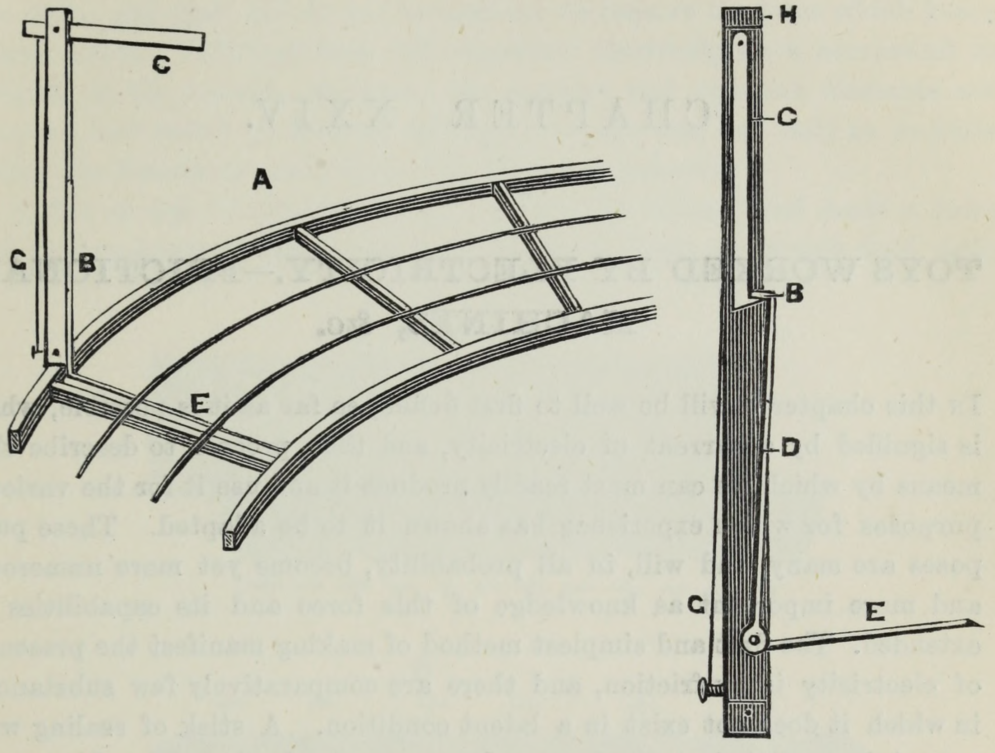


Fig. 114.—Self-Acting Signal.

CHAPTER XXIV.

TOYS WORKED BY ELECTRICITY.—FRICTIONAL MACHINES, &c.

In this chapter it will be well to first define, so far as it is possible, what is signified by a current of electricity, and then proceed to describe the means by which we can most readily produce it and use it for the various purposes for which experience has shown it to be adapted. These purposes are many, and will, in all probability, become yet more numerous and more important as knowledge of this force and its capabilities is extended. The first and simplest method of making manifest the presence of electricity is by friction, and there are comparatively few substances in which it does not exist in a latent condition. A stick of sealing wax or resinous substance affords a ready means of experiment, so does a rod of glass or a glass bottle, a bit of gutta percha or vulcanite (indiarubber hardened by sulphur)—any of these will serve the purpose. Take, for instance, a dry rod of glass, and give it a rub on the coat sleeve, and if held over a feather or light bit of paper or bran it will attract it like a magnet, but presently it will be repelled and thrown off, to be again attracted and again repelled, until, presently, the effect ceases.

This attracting and repelling force is electricity. It exists in the glass, or rubber, or both, in a latent or invisible form until brought into activity by the friction. Moreover, it is plain that we may compare it with a mechanical force; it will do a certain amount of work—lifting and repelling in this case—until, in some way, a balance is attained. Then its work ceases until we again call the latent power into operation. Upon the whole, the most convenient theory, perhaps, is to consider electricity a fluid capable of being directed in a certain course like a stream of water or current of air; but we are obliged also to recognise it as a *compound* fluid or a kind of double force, quiet and peaceable till we separate its component parts, when there is no rest until they come together again. The one part is known as positive, the other as negative electricity. Let A (Fig. 115) represent a closely coiled spring. We may mark its coils alternately plus and minus (+ —) to represent positive and negative. Now, if we stretch the coils open, as seen at B, their tendency will be to re-unite, and they will do so the moment we remove the force which keeps them apart. This may very well represent electricity as a compound in which, in its normal condition, the positive and negative elements are united, but which by friction are made to separate, but only to re-unite when the necessary conditions of re-union are present.

Other causes besides friction will destroy the balance and cause a state of tension between the positive and negative elements of this fluid, and, except for experimental purposes, frictional electricity is not now made use of, as there are more convenient modes of producing electrical tension. Bearing in mind this compound nature of the fluid, we may also consider it (as already stated) as a current or stream, capable of flowing through, or by means of, suitable conductors, but refusing to travel by these conductors unless they are made of certain materials. Acid and salt water and metals are good conductors; glass, earthenware, india-rubber, and resinous substances are bad ones, and it will be at once noticed that these are the substances in which electricity is excited by

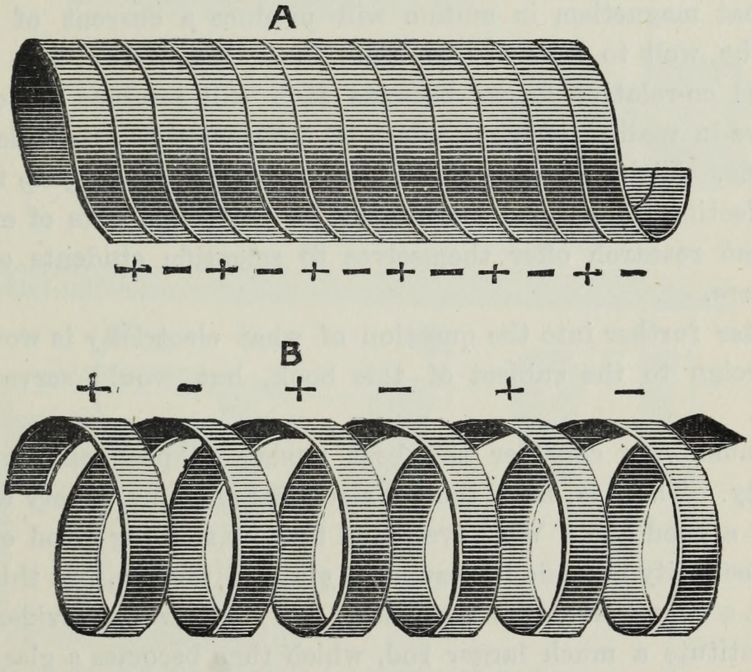


FIG. 115.—THEORY OF POSITIVE AND NEGATIVE ELECTRICITY.

friction. It has, however, been proved that electricity can be excited in the metals, but it passes off or resumes its normal condition so immediately, owing to their rapidly conducting power, that its presence in a state of tension is but momentary, and does not so remain long enough to develop visible electric phenomena.

In toys worked by electricity the motion may be due to attraction and repulsion acting alternately by some special arrangement of the apparatus or machine, or by the current itself flowing in one direction only, and without reference to its compound nature; or by inducing magnetism in a piece of soft iron, and making use of this as the motive power, the latter being very much used. For it is found that magnetism—that subtle force residing naturally in the loadstone—can be induced in a rod of iron by causing a current of electricity to flow around it, and, on the other hand, that magnetism in motion will produce a current of electricity. It may be well to remark here that Heat, Magnetism, and Electricity are called co-relative forces, because each will produce the other as if they were in reality the same thing, in different states or under different conditions. Light is again allied to these forces, making up the quartet and perfecting the natural harmony. No better subjects of experiment, study, and research offer themselves to scientific students or scientific toy-makers.

To enter further into the question of what electricity is would be not only foreign to the subject of this book, but would serve no useful purpose.

We must now consider the best modes of producing or exciting electricity. There is, first, the old electrical machine, a very easily made toy, and a good one. We have found that by rubbing a rod of glass the latent electricity is made to assume a state of tension, but this is practically not a very convenient apparatus. It is, however, evident that we can substitute a much larger rod, which then becomes a glass cylinder, and we can mount it upon an axle with a winch handle to turn it, and can then apply a fixed rubber to it. We need not use a solid cylinder, because it is found that electricity lies upon the surface only, so that a hollow cylinder will serve perfectly well. In most books on electricity a machine made with an empty wine bottle as its cylinder is shown. This will no doubt serve the purpose to a certain degree, but it is difficult to fit up, and generally so uneven that a rubber cannot be made to apply very efficiently to its surface, even though pressed against it by a spring. Glass is very cheap, moreover, and when a thing of this kind is to be made and used for scientific experiment, it is better to lay out a shilling or two in order to obtain materials sure to prove satisfactory. A cylinder

6in. long can be bought for 2s. 6d., or less, and as there is nothing else that need be purchased to complete the machine, it is well worth the moderate outlay. I shall therefore presuppose that a small glass cylinder has been purchased.

This will be like A, Fig. 116, with two necks, one at each end, meant to receive a pair of brass or wooden caps (like B) to support the axles on which the cylinder is to turn; one axle to receive the handle, or a pulley, if a multiplying wheel is to be used. In a machine I myself made, which works very well, I turned a pair of caps of dry boxwood and subsequently coated them with sealing wax varnish. They were drilled to receive a wooden axle made to pass quite through the cylinder, and then a saw cut was made across the caps on the outside of each, like C. The axle D, of hard wood, being passed through the caps, the cylinder is secured by a pair of pins, which lie in the saw cuts, and compel the

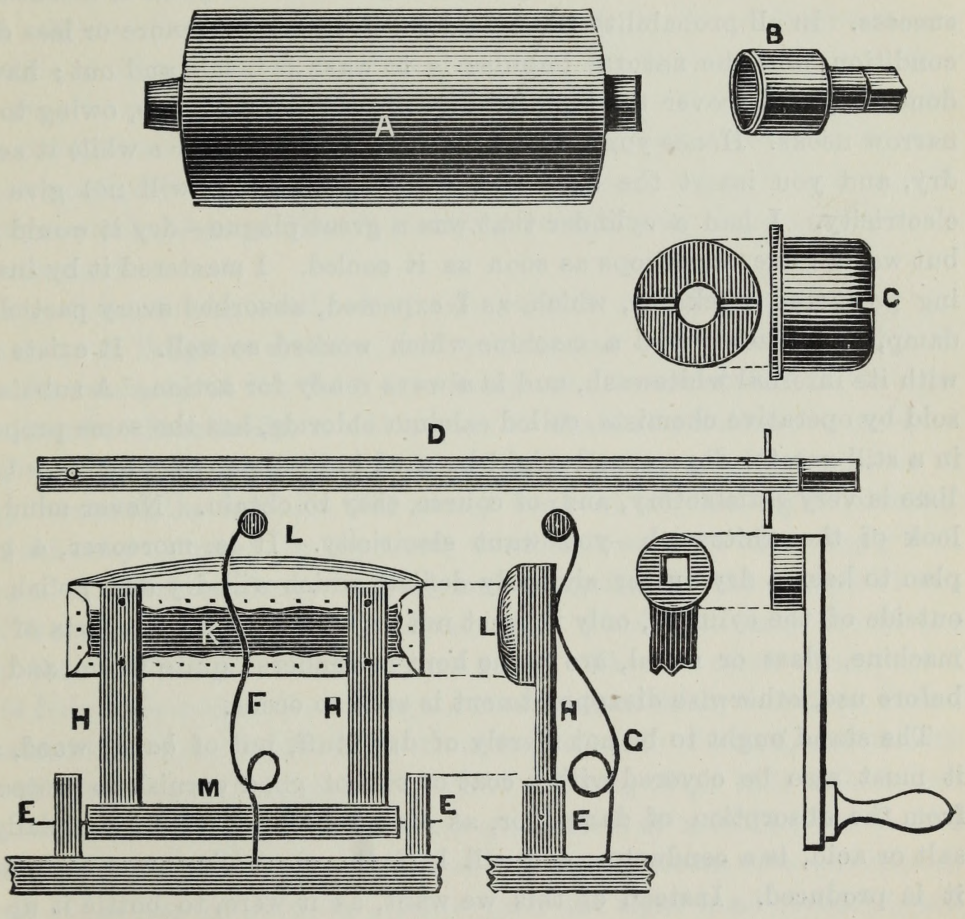


Fig. 116.—Details of Electrical Machine.

cylinder to turn with it, while at any moment, by taking away the pin farthest from the handle, the axle can be wholly removed, and the cylinder taken out to be dried or cleaned. The caps should be secured with electrical cement, composed of rosin melted in a ladle, and brick dust or red lead stirred into it while hot. This is poured into the cap, the neck of the cylinder having been warmed, and when the latter is pressed on it will be held with sufficient firmness. The cap should not be too tight a fit, but made so as to leave room for the cement.

It must be remembered that perfect dryness of the glass is essential to success. In all probability the cylinder will arrive in a more or less dirty condition, and the natural impulse is to wash it inside and out; having done so you discover the impossibility of wiping the inside, owing to the narrow necks. Hence you put it before the fire, and after a while it seems dry, and you insert the axle and grind away, but it will not give out electricity. I had a cylinder that was a great plague—dry it would not, but was all over dewdrops as soon as it cooled. I mastered it by inserting powdered quicklime, which, as I expected, absorbed every particle of damp, and I never had a machine which worked so well. It exists still with its internal whitewash, and is always ready for action. A substance sold by operative chemists, called calcium chloride, has the same property in a still greater degree, and might be used in the same way, but powdered lime is very satisfactory, and, of course, easy to obtain. Never mind the look of the whitewash—you want electricity. It is, moreover, a good plan to keep a dry duster similarly defiled, which will dry and polish the outside of the cylinder, only it must not scratch it; and all parts of the machine, glass or metal, are to be kept or rendered quite warm and dry before use, otherwise disappointment is sure to occur.

The stand ought to be not merely of dry stuff, but of *baked* wood, and it must also be covered with a coat or two of good varnish to protect it from the absorption of damp, for, as stated before, water, especially if salt or acid, is a conductor, and will lead the electricity away as fast as it is produced. Instead of this we want, as it were, to bottle it up for use, or to lead it where we please before it has a chance of getting dissipated. Nearly all failures with frictional electrical machines and apparatus arise from dampness or atmospheric influences upon the material of which the machine is made; and, therefore, all woodwork should be coated with a good varnish—that made by dissolving sealing wax in spirits of wine or naphtha being very generally used for this work. The stand of the electrical machine need only be sufficiently long to take the uprights which support the axle of the cylinder, but it should be wide enough to allow the pedestal or support of the prime conductor to be attached firmly to it. True, this support is often made separately, but this is not so convenient, nor does it give so firm a base to the conductor, which then is inclined to fall over, when for experimental purposes other apparatus is attached to it. Do not use deal for the stand or for the uprights. It is just as easy to obtain ash, beech, or mahogany, any one of which is very much better than deal, which is very liable to split, and is of too yielding a character for this work. Mahogany, dried or baked, is probably the best, but beech or ash is satisfactory. Let the uprights be fitted by mortise or dovetail, and glued into their appointed places. They may be cut out of the same strip, which is planed truly square, and then sawn across, but of course may be worked independently. The axle should not be merely passed through holes, but these last should be bushed with stout glass tubes to make the best possible job, as you thus secure more perfect insulation, the electricity not being able to fly to the woodwork and escape. Glass is always a good insulator—earthenware is likewise good.

Keep this also in mind. You are going to excite into activity the electricity on the glass cylinder, and your object is to collect and use it. But the tendency of the fluid is to escape or to re-establish the balance you disturb. Practically, it will escape to the earth, unless you prevent it by leaving it no conductor to travel by. If the air is damp, as in foggy weather, the machine will rarely work at all, the fog conducting the fluid away at once. In dry frosty weather it answers exceedingly well always. Another tendency to be guarded against is the escape of the fluid from projecting points of metal, from which you may see in the dark that it flies off like a luminous brush. There is often unsuspected waste from this cause. In making an electrical machine, therefore, round off corners and place knobs upon the ends of all rods of metal, and smooth all surfaces as much as possible. The drawing (Fig. 116) affords full instructions in the details of the simplest form of machine, but it is a good plan to increase the speed of the cylinder by means of a multiplying wheel, which can be fixed on a stud upon the right hand standard, and have a cord carried over a small pulley on the axle of the cylinder. The only practical objection to this arrangement is that cords are apt to get slack or to slip, or in one way or another cause trouble; but a leather cord, united by hook and eye, screwed to its ends, such as can be purchased at any tool shop, is by far the best and freest from drawbacks of the above kind.

The rubber or cushion is the next consideration, and here, again, I have practised a rather unusual mode of construction, which is, notwithstanding, to be recommended. We have to arrange this so as to press against the cylinder as it revolves, and there should be some contrivance by which this pressure can be increased or diminished at pleasure, while, again, the cushion should be readily got at for scraping, cleaning, or fresh amalgamation (the latter will be explained in due course). First make the frame like H H K (Fig. 116), of which the top is a flat board 2in. wide, on which to make a leather cushion stuffed with dry hair, *quite* dry and warm. L is the cushion, $\frac{1}{2}$in. thick, and as flat on its face as it can be made. H H are mortised or half-lapped into M, which is a bar of wood (ash or beech) a little longer than the cushion, which is the length almost of the cylinder, and it is pivoted to short upright standards, E E, fixed securely in the stand of the machine. Thus arranged, we can turn back the cushion completely out of the way at pleasure. The spring to keep it pressing against the cylinder is of stout brass wire, about as thick as a crow quill or stout whipcord. This is best as shown at F, and again at G, and the end set in a hole in the stand of the machine. It is easily adjusted in respect to the pressure it is to exert by bending it more or less, and it can be lifted out and removed at pleasure. There should be a knob at the end, but otherwise this part of the machine must not be insulated, and it will be all the better if a brass chain is attached to this spring, and the end allowed to rest on the floor. We want to get here as much of the earth's electricity as we can, and it is thus the supply is kept up which we take from the glass by friction. For we must find some reservoir of this mysterious force, and if we were merely to get from the glass all that is about it, the result would be a mere nothing, a spark and no more. Now the earth is the great storehouse, which is practically inexhaustible, and we therefore bring it into the circuit as stated, and make all possible use of the supply thus obtainable. As fast as we draw from the cylinder the earth supplies more, and we may grind away as long as we like with continuous good effect. But, at the same time, I may state that we cannot keep on bottling what we obtain. After a while the tension is so great that with a loud crack the balance is restored, sometimes causing fracture of part of the apparatus. Nature, on a grand and gigantic scale, works in the same way. Electric disturbance takes place; tension is set up and increases until the discharging point is reached, then come a flash of lightning, a thunder clap, and, for the time, equilibrium is restored, to be again and again disturbed, however, until the storm ceases, *i.e.*, until the atmospheric electricity has resumed its normal quiescent state.

Fig. 117 shows an electrical machine put together, constructed in accordance with details already given. A is the glass cylinder turned by a winch handle, M. F F are the standards mortised into the base board. D is the roller of the cushion on the further side. K is a silken flap attached to the cushion and varnished on the upper side. Its object is to prevent the electricity which is excited by the cushion or rubber escaping before reaching the prime conductor, B. This conductor is usually a bit of brass or tin tube, about 2in. to 3in. diameter, mounted on C, a glass insulating pedestal. A row of points of brass wire stand out from its side, and are made just to escape contact with the cylinder. These points collect the electricity, and lead it to the conductor, from which it cannot readily escape, because of the insulating pillar. The conductor need not be of metal. A very good one may be made like G, of wood coated with tinfoil, smoothly laid on, or even coated with black-lead, such as is used for grates, because the electric fluid lies upon the surface only. The points are often put at one end, so that anything can be hung from a rod and ball fixed into the opposite end. If the conductor is of wood care must be taken that the metallic coating touches H and this other rod. An insulating stand is absolutely necessary and easily made by inserting a rod or tube of glass into a wooden block. A glass bottle is often used to form such a stand. I have a conductor made of a tin tube with rounded ends, at one of which the points are placed, and a wire nail or screw, soldered by its head to the middle of the tube, goes

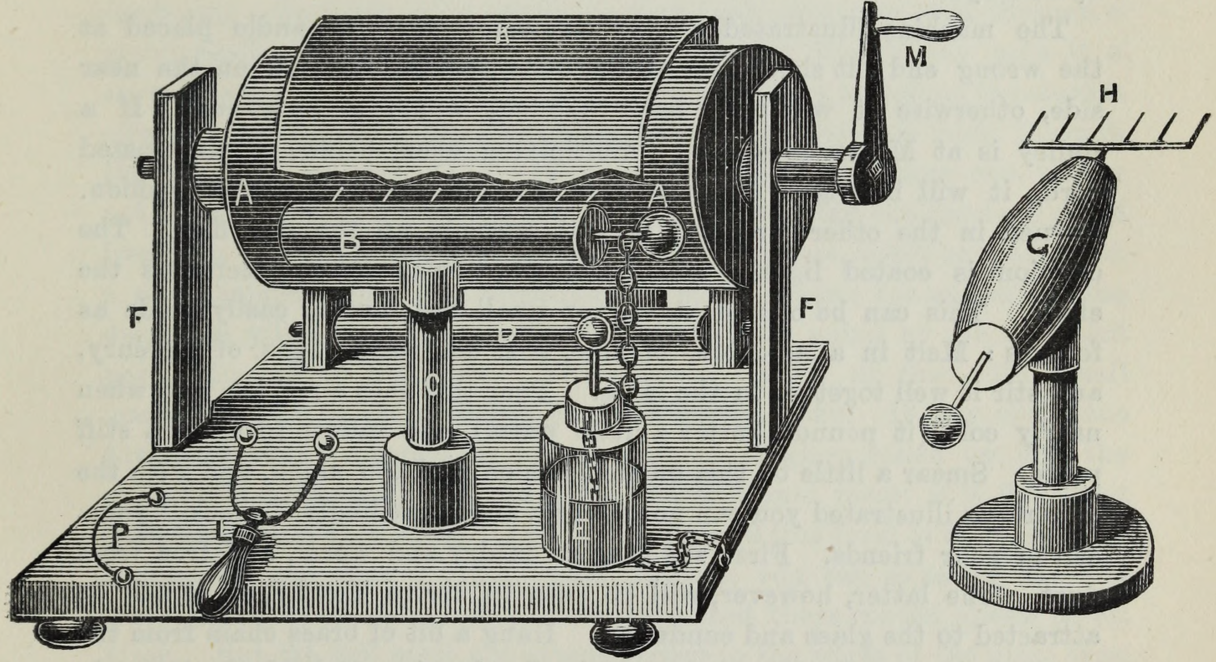


FIG. 117.—CYLINDER ELECTRICAL MACHINE.

into the cork of an empty pickle bottle containing a few bits of lead, to make it stand more securely. Nothing can answer better. Round all ends, leaving no sharp edges. A door knob soldered into the end of a tube answers well for this. Where you cannot get rid of an edge, coat it well with sealing wax varnish. E is called a Leyden jar, and is used to bottle up the electricity, which, however, does not fill the bottle or saturate the air inside it, but only affects the surface of the metal coating, the latter being tinfoil pasted on outside and in, to half the height of the jar. A pastrycook's jar makes a very good one. The wire with the knob is passed through the cork and connected with the inner coating of foil by a bit of brass chain. L is a discharging rod, of which more will be said by-and-bye.

The machine illustrated has by an error had the handle placed at the wrong end; it should be at the other, or the cushion on the near side, otherwise it will turn back handed, which is awkward. If a pulley is at M, however, and a multiplying wheel below, with a crossed cord, it will be right, as the cylinder will turn *from* the cushion. Turned in the other direction it will crumple up the silk flap. The cushion is coated lightly with amalgam, which vastly increases the effect. This can be bought at 1s. per small box, but is easily made as follows: Melt in a ladle 1oz. of zinc, ½oz. tin, warm, 1½oz. of mercury, and stir it well together in the ladle. Pour this into a mortar, and when nearly cold (it pounds better a little warm), add tallow to make a stiff paste. Smear a little of this on the cushion, not too much, and with the apparatus illustrated you can go to work, and exceedingly "shock" yourself or your friends. First see that all is dry and warm, and free from dust. The latter, however, will be sure to arrive shortly, as it will be attracted to the glass and conductor. Hang a bit of brass chain from the conductor to touch the outside of the Leyden jar, or hold the latter in your hand, grasping its outer coating, and presenting its knob to the prime conductor (this will not electrify or affect the holder in the least). If all is right, and the knob does not actually touch the conductor, a stream of sparks will fly from the latter to the knob of the jar, which will presently be highly charged. This charge, or electrical tension, is on the glass on each side, conducted to it by the metallic coating, and if this coating is not pasted, but made to slip off, it may be removed, and will not be found to be in an electrical condition; and if another coating be now substituted it will answer just as well. There may be possibly some special state induced by or upon the foil while contact remains with the glass, but it is supposed to act chiefly as a conductor to spread the fluid over the glass. The result, however, is that positive and negative electricity are respectively excited on the inside and outside of the glass jar; and, to restore the electricity to quiescence, they must now be allowed to unite. Holding the bottle by its coated or conducting surface in one hand, apply the knuckle to the knob. You thus become the conductor, and receive a shock, as the positive and negative particles unite with a sharp crack. Stand the jar on the table in this experiment, or probably you will drop it, especially if it be a large one, in which case you will feel the shock at least up to the shoulders.

Now, it is plain that you need not become the conductor unless you prefer it. You may take L, the discharger, or merely a bent wire, and bring the knobs one to the outside coating and the other to the knob, you will thus produce a spark, but get no shock, because metal is a good conductor. So much more readily, in fact, will electricity pass through a metal conductor than through the human body, that if you take P, a curved brass wire, in your hand and apply the knobs as before, the electricity will not fly off to the hand, but the jar will discharge itself through the wire. If, however, there are several such jars, or a large one, this is not a safe method, unless the wire is of good size, and the hands dry and free from perspiration. The discharger, in that case, must be made with a glass handle, or serious consequences might ensue; for sometimes the discharge will branch like forked lightning, part going by the wire and part flying off to the body. There is no danger of this with small machines, such as the reader is likely to buy or make. It may strike the toymaker that a Leyden jar is but a sheet of glass rolled up into the cylindrical form, and that the same effects would result if a flat sheet were coated on each side. And so it will, and this form is more easy to make, and will answer often better, because you can so easily dry and warm it on both sides. I have largely used these coated sheets of all sizes. But the foil must not extend nearer to the edges of the glass than about an inch, or the tension will sometimes cause a discharge to take place over the edge, the electricity leaping the narrow insulating border of glass.

One advantage of a flat plate of glass is that it is so easy to coat it with the foil, and having so coated it, to use it as an accumulator of the electric fluid. It is charged, of course, in a similar way. The plate is laid flat on the hand, which is then in contact with the foil on its under side, and it is held so that sparks from the conductor fall on its upper coating; or it is laid flat on the table, and a chain from the prime conductor allowed to rest on its upper surface; or the chain may be on the table, and the plate laid upon it, conducting the charge to the under side. In either case one side is directly and the other indirectly charged; the latter by what is called induction, for if positive electricity is made to accumulate on one side, negative is developed on the other, and only by the union of the two is discharge accomplished and equilibrium restored. The plates of glass are so cheap that various sizes may be made. I have them from 3in. or 4in. square to 14in. or more, and one of thicker glass, 2ft. long by a foot wide, but the shock from this is not agreeable. The several plates or jars can readily be used in combination, by connecting all the lower metallic surfaces, and all the upper by a wire laid upon them, making a battery equal to one large plate.

Some pretty effects are produced by making scratches through the foil, or putting it on in a series of diamond-shaped bits not quite touching each other, when, during the process of charging, the electricity will be seen sparkling all over it as it leaps the intervals, and when discharged, the whole surface is momentarily rendered very brilliant. Any device or names may be thus scratched through the foil and illuminated. In short, in scientific toymaking, electrical apparatus affords great facility for amusement and instruction, and, in a darkened room, the pale purple spark is very beautiful.

An electrical machine will often work better if a chain be hung on the back of the cushion and suffered to trail upon the floor. The cushion must on no account be insulated on glass supports, unless this chain is used to bring it into communication with the earth. If made as directed, it will act without such chain, as the wood is a fairly good conductor, but it will be still better if the cushion is backed by a bit of wire gauze, or by a plate of brass under the wood back, and a screw passed through this to touch the metal. Then, by hanging a chain on the screw, the conductive arrangement is very perfect. We learn much by most simple experiments of this kind. Stand th machine on a sheet of glass laid upon the table, or upon four saltcellars of glass, or tumblers, or earthen jars, and you will grind away in vain. Then, while all is thus arranged, drop a chain from the cushion to the floor or table, and at once electrical effects become possible, the earth keeping up the supply; at any rate this is the apparent cause, and may be accepted as a satisfactory theory. Then, the secret of success is, *do not let the electricity get away to earth again until it has passed through whatever apparatus you please.* Keep it as your slave until you have done with it. It will give light and heat and motion and magnetism, and various chemical effects, such as separation of compound bodies and deposition of metals.

In making a Leyden jar we coat the inside of it with foil. Will any other metallic conductor answer? Why not? Fill the bottle half full of iron filings, and you will find it equally satisfactory. Try water, especially if salt is dissolved in it, and the result will be the same. Vary the experiment thus: Coat the outside of a tumbler with foil, fill it half full of water, and charge it by dropping a chain from the prime conductor into the water while holding the tumbler by the covered portion. Remove the chain by drawing the tumbler gently away. Now drink if you can. The moment the water touches the lips the electric circuit is complete, the lips form one end of the discharger, the hand the other, and equilibrium is restored with a spark and shock. A small tumbler will be quite enough for this experiment. Charge it again, and, holding it by the outside coating, dip the finger of the other hand. The shock will be felt, and more pleasantly than through the lips. All these experiments depend on the same fact—the two surfaces of the glass are charged with positive and negative electricity respectively, and are then connected by a conductor, metal or water, or some part of the body, and discharge takes place with a spark.

To make the toymaker himself a prime conductor. This is easily done. Consider for a moment what the peculiarity of the other conductor is. It is merely a conducting material insulated on a glass leg. Let anyone place himself in a similar position, and he will fulfil the task equally well. Turn upside down upon the floor an earthenware pan, or place four glass saltcellars on the floor and lay a board upon them, and in either case you have made for yourself a non-conducting stand upon which to mount. Take in one hand a chain from the prime conductor, or lay one hand upon it, taking care not to allow the clothes to touch the table, and you then become to all intents and purposes a part of the prime conductor. Now let someone turn the machine, and if anybody standing on the floor presents the knuckle to the unhappy toymaker's nose, or lip, or ear, a spark will pass from him with the same sensation as that caused by the prick of a needle. While standing in this insulated position a Leyden jar can be charged by sparks drawn from the living machine.

We must now consider one or two other features of the apparatus apart from the Leyden jar and electric discharge. I stated the fact of attraction and repulsion, but did not enter into details. Hang over the small wire of the conductor a narrow strip of paper folded so that the two parts touch, or a bit of silk, and turn the handle of the machine. The two parts will instantly separate. Both are similarly electrified, and repel each other. Make an insulating stand by fixing a bit of glass tube in a disc of wood (as in B, Fig. 118), or take a corked bottle and stick into its cork a piece of brass wire bent at right angles similar to that shown in A. From it suspend by a filament of silk a pith ball, covered with a bit of gold leaf or tinfoil. Electrify this by placing it near the conductor, or by a bit of wire carried from the latter to the horizontal arm. The ball will fly to the finger after being electrified, and having thus discharged its electricity will drop back again to its former position. It is easy to make a light body oscillate by electricity in this way, and there are many simple arrangements to show this phenomenon. One of the usual ones is the following: C (Fig. 118), a disc of metal or coated cardboard is hung from the prime conductor, thereby becoming a part of it, and below it is a similar disc on a wooden or metal stand. A figure is cut out of paper and laid on the lower disc, or a pith ball is used, or a little bran. As soon as the cylinder of the machine is turned these are attracted, as all light bodies are, and fly up to the upper disc. As soon as they touch it they become similarly electrified and are repelled. No sooner do they fall again on the bottom disc than they part with the charge, which escapes to earth, and they are at once attracted as before to the upper disc, as there is more electricity in the prime conductor than they can take up by a single momentary contact; even after one or two turns of the cylinder they contiuue to dance up and down for a few seconds after the cylinder ceases to revolve, until gradually all the electricity is dissipated. We find, then, that bodies similarly electrified repel each other, and, when differently electrified, are mutually attracted.

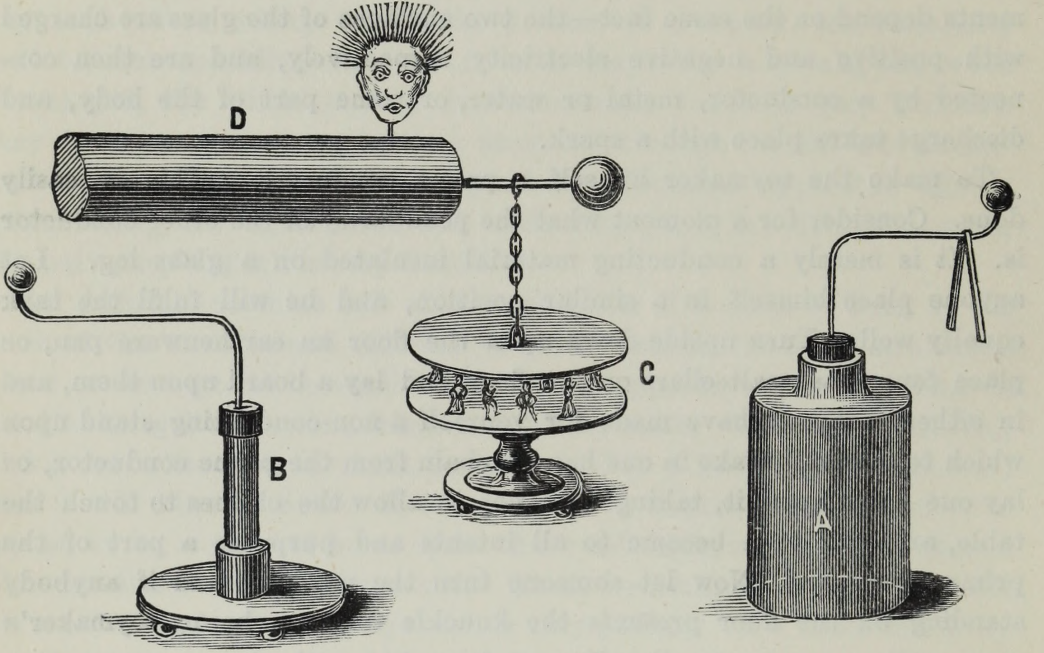


FIG. 118.—ELECTRICAL APPARATUS.

Another experiment of a similar character may possibly give a clue to the sharp shower accompanying a thunder storm. Hang a sponge, wrung out just so much that the water will not drip from it, to the prime conductor. The moment the machine is set in motion, drops begin to fall, which, as the electricity increases, becomes a shower. The drops being similarly electrified, repel each other, and are also repelled by the sponge itself. If the latter is a miniature representation of a thunder-cloud we can see why, in such a case, the storm is produced, the cloud repelling, while, at the same time, the earth attracts the electrified water. There is no doubt about the attraction and repulsion constituting a powerful force, for, if a tube is drawn out to so fine an orifice that water will not flow out, yet, if we electrify the fluid, it will spurt forth as it would out of a squirt, and, if these experiments with such a very minute quantity of electricity give results of this kind, we can readily conceive what will ensue when Nature works on so gigantic a scale. Another common experiment depending on the same force is to make a doll's head of exceeding ugliness out of a bit of wood, and adding a quantity of tow for hair, to set it up by means of a short wire in a hole on the prime conductor (D, Fig. 118) of the machine. Electrical repulsion affecting each hair causes the said hair to stand on end in a most grotesque fashion. By many other simply constructed pieces of apparatus the phenomena of frictional electricity can be shown; but in practice there are many drawbacks to this method of obtaining electricity. The simple fact of there being an absolute necessity of working a handle to set the fluid in motion, precludes its adoption for general purposes, and I shall now pass from frictional to galvanic electricity, suitable for telegraphing and other purposes.

CHAPTER XXV.

TOYS WORKED BY ELECTRICITY.—GALVANIC BATTERIES.

WITH galvanic electricity, so long as the battery is in order, and metallic connections perfect, a constant supply of the electric fluid is maintained in the convenient form of a ceaseless current flowing through such apparatus as may be connected with the battery. Like a faithful servant awaiting orders, the power is always ready for transmission in any direction through the conducting wires. With the fluid, the toymaker has at hand a ceaseless field for the exercise of his ingenuity. Telegraphs and engines, clocks and bells, are but a few of the many interesting scientific toys which can be constructed with the least possible difficulty, and all have this great advantage over such as are actuated by steam, that they need no lamp or fire. There is no danger of explosion, no liability to set up an involuntary conflagration; hence, also, the solder will not melt, and the apparatus tumble to pieces; and one battery will work a number of different toys. In addition to imparting motion to miniature machinery, a little toy electrotyping and plating can also be carried on; and some of the toys, moreover, can be constructed so as to answer useful purposes, notably electric bells, which are of very simple arrangement, and offer but little difficulty to an amateur electrician. The one consideration (as in frictional electrical experiments) is to know exactly the laws which govern the force. Having studied and thoroughly apprehended these, it will not be a difficult matter to devise toys which depend upon them for their action.

Many of our most valuable discoveries have resulted not, as has been so often said, by accident, but from the attention paid by men of scientific attainments to phenomena which less observant students pass by unnoticed. This was emphatically the case with galvanism or electricity, produced by chemical agency, which proved a more valuable (because more manageable) source than friction. It was noticed that when two metals, one more oxidisable than the other, were immersed in a fluid capable of acting upon the oxidisable one, a current of electricity was set up as soon as metallic connection was made between them, and that it ceased to flow when this connection was interrupted. Here was quite a novel mode of exciting electricity, but it was soon proved beyond a doubt that the fluid was identical with that previously obtained, although in some degree differently disposed. It is, in fact, when thus set in motion, more truly a current of electricity than when produced by the frictional process. With the latter I have shown that we can collect it by means of a coated sheet or jar of glass, and then discharge it in a moment with a report and shock if the operator is not protected.

The shock produced by galvanic electricity is continuous, a series of shocks succeeding each other so rapidly that they produce a violent cramp in the muscles, which may be so severe as to produce partial or permanent injury. It is the same kind of difference as exists between a violent blow and continuous pressure; they are different in kind and degree, yet the result may be the same, namely, crushing of the parts subjected to the force. But however amusing it may be to give a friend a shock, this is not the scientific mode of using the electric current, and will not conduce to the furtherance of the art of toymaking—it merely shows the effect of electricity upon our animal economy.

The galvanic battery in its simplest form consists of a slip of zinc and one of copper inserted in a vessel containing salt and water, or dilute sulphuric, or hydrochloric acid and water. The current produced by this is sufficient for some few purposes, such as electrotyping on a small scale, *i.e.*, depositing metals from their solutions, but is not powerful enough to set in motion mechanical toys. The metals must not touch where inserted in the solution, but may be brought into contact by leaning against each other at their upper ends, or by means of a copper wire or one of platinum, both of which are excellent conductors. In point of fact, metallic connection is the requisite for the passage of the current, but some metals have proved more suitable than others for the purpose. Platinum is too costly for general use, and next to this copper wire, especially if covered with silk, cotton, or gutta percha, is the most serviceable. This, however, owing to its commercial value, has to be set aside if great length is required, when iron wire usually takes its place. It is iron wire which is used for ordinary telegraphic communications, but it is coated with zinc to preserve it from the effects of the damp atmosphere, and is then known as galvanised wire. The zinc, however, while preserving it from rust, greatly reduces its tensile strength, rendering it comparatively brittle. It seems to penetrate its substance to a certain extent.

We need some ready means of detecting the presence of the galvanic current, and a magnetic needle or small compass admirably answers the purpose. The moment the current is made to pass, by connecting the wires of the battery, a magnetised needle placed under or above it is deflected to the right or left, standing, if the current is strong, at right angles to the wire. This is the principle of the needle telegraph invented by Wheatstone, and which is still used, although others are gradually superseding it. But the simple battery described is not sufficiently permanent and steady in its action to supply electricity for telegraphic purposes, and the arrangement of Daniell is, on the whole, the easiest and best for the toymaker to construct. The elements are zinc and copper, as before, the exciting fluid dilute sulphuric acid, but the zinc is inclosed in a porous jar of earthenware, or in a vessel of canvas or brown paper, and is then kept apart by itself, but standing within the copper cylinder. The latter is filled with a solution of sulphate of copper kept saturated by means of crystals of the salt so placed as to be gradually dissolved. Fig. 119 represents this arrangement in detail.

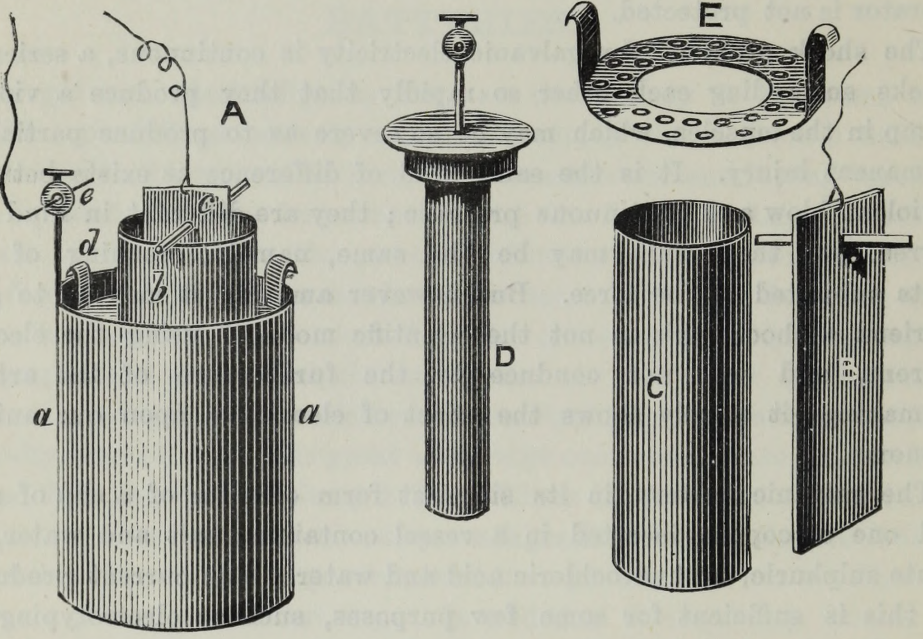


FIG. 119.—DETAILS OF GALVANIC BATTERY (DANIELL'S ARRANGEMENT).

A is the battery complete ; *a* is an outer vessel of copper, forming at once the negative element and the cell to contain the solution of sulphate. The capacity is from 1 pint to 1 quart, but may, of course, be varied to suit circumstances. A gallipot will do just as well, with a strip of sheet copper bent into the form of a cylinder placed inside it (*b*) ; and C represents a porous cell, usually of plaster of Paris, seen again at *b* ; E is a circular shelf of perforated copper, with hooks to support it inside the outer vessel. It serves to steady the porous cell which stands within it, and also to support the crystals of sulphate of copper. B is one form of zinc, a flat plate supported by a cross wire, or a bit of wood or tobacco pipe placed through a hole in it, and resting on the edge of the porous cylinder. Instead of this, a neater plan is to cast a cylindrical rod of zinc as at D, and to solder in it the wire which carries the binding screw. To fit over this, a round disc of wood is made with a turned flange or tenon, fitting easily inside the porous jar, and a stout wire is soldered at *e* to the copper cylinder.

With this battery, if the zinc is amalgamated, no wasteful action goes on until connection is made by a wire between the copper and zinc elements. As soon, however, as this is effected, the zinc begins to be acted on by the sulphuric acid, and a current of electricity is set up. The zinc is gradually dissolved, and the metallic copper is deposited in the form of a red-brown coating all over the inside of the outer vessel, thus partially exhausting the copper solution. The waste is, however, at once supplied by the crystals of copper salt placed on the shelf. We have here not only a battery, but what is called a decomposition cell, in which the copper is constantly being separated and deposited from the sulphate of copper solution. It is this coating which keeps up the steady action of the battery, the zinc element in the simpler form gradually forming a deposit on the face of the copper, while bubbles of hydrogen from the zinc solution also attach themselves and diminish the surface of the metals exposed, thus reducing practically the size of the plates.

In some batteries on this same principle the porous cells are made differently, being inserted as divisions in a long, narrow wooden trough, which is thus divided into compartments. Square plates of zinc and copper are then used, connected by a copper band, and these are hung over the porous divisions, so that a zinc and a copper plate face each other in each cell. Thus far the battery is the Cruickshank, and, filled with sand saturated with the acid solution, was long used for telegraphy. But the cells, being now subdivided by porous plates of unglazed earthenware, so that the zinc and copper of each cell, though facing each other, are yet kept apart, we have the Daniell principle, merely arranged somewhat differently. The cells are, of course, charged, as before, with zinc-sulphate solution next the zinc, or sulphuric acid or salt and water in the cells in which the zinc plates are suspended, and with sulphate of copper in the others. With covers to prevent undue evaporation of the fluid, this is an excellent battery for telegraphic purposes and for working all kinds of toys. From one to six cells, holding plates 3in. square, will be quite enough for experiment, and a dozen cells will work a telegraph with some miles of wire between the intruments. It will be well, I think, before describing electric toys, to advert to one more fact of galvanic electricity. If a bit of soft iron is surrounded by coils of insulated wire, or wire covered with cotton or silk or other substance, so as to prevent entirely metallic contact between adjacent coils, the iron will become a magnet while the current passes along the wire, but the magnetism will cease as soon as the current ceases.

No more important discovery was ever made; and electric bells, clocks, and telegraphs, with electro-motive machines of various kinds, depend upon this property of the electric fluid.

CHAPTER XXVI.

TOYS WORKED BY ELECTRICITY.—MOTIVE MACHINES.

The first and simplest of electro-motive toys I will now describe is actuated in the way as mentioned in the last chapter. A, Fig. 120, p. 258, is a wooden stand holding, in an upright position, the horseshoe magnet (B) ; this is a permanent magnet of hard steel, of which the north and south poles are marked N.S. Between them rises an upright steel rod, on the pointed end of which a soft bar of iron (E), wound with coils of covered copper wire, is balanced to turn easily. The ends of this wire, which are uncovered, are formed into loops, from which hang loosely two bits of straight wire, amalgamated with mercury at their lower ends, and dipping into a circular trough of mercury, divided across by a partition of wood.

The wires from the two elements of the battery are brought through the bottom of the circular trough into the mercury, one on each side of the central partition. The result is that when the hanging wires are each in the mercury, one on each side of the partition, the course of the electric current is complete, and the fluid pervades the wire and renders the soft iron magnetic, establishing in it a north and south pole. But like poles repel each other, and unlike attract, and the revolving magnet which forms an armature to the permanent one, takes up a position at right angles to the other. But matters are so arranged that by this movement the hanging wires have been carried across the central division of the mercury reservoir, and have each dropped into the other's original place, thereby reversing the current. The poles are by this changed, the north becoming the south, and *vice versâ.* The consequence is that with the impetus which carries it on a little further the circuit is completed, only to commence as before the moment the pendent wires again come into their first position. A similar apparatus can be made, in which the coils and soft iron form the horseshoe magnet and the suspended needle the permanent one. This answers as well, but it is more difficult to arrange a commutator to reverse the current.

Passing from this, which, although it will keep in rotation, has very little power, we may go on to those in which there are several magnets arranged in a circle, coming successively into action. The main difficulty with all electro-motors is that, great as is the power of attraction between a magnet and its keeper, the distance is but small through which this is exerted. If the keeper be nearly close, it may be attracted with immense force, but at an inch distance the power of attraction may be quite inappreciable. Battery power also, when it is obtained, as it usually is, by the sacrifice of the zinc, is too costly for economical application. This has much retarded research in this direction, and only recently have fresh attempts been made to arrange something practically useful as an electro-motive engine. As yet, however, nothing has been

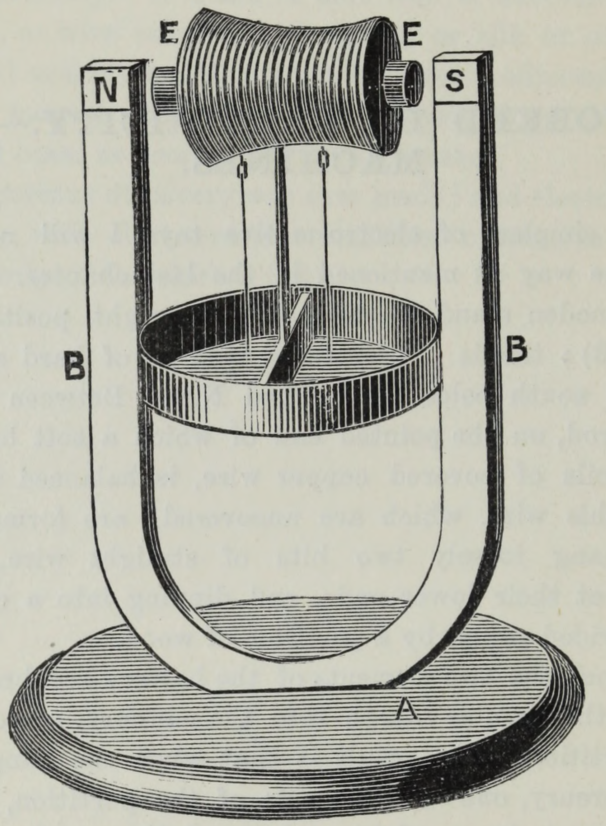


FIG. 120.—SIMPLE ELECTRO-MOTIVE TOY.

contrived which can be called even promising. There appears to be a source of enormous power at hand, and yet, from the above reasons, it appears impossible to apply it satisfactorily. It is easy to arrange the machine, and no power is so well controlled, but unless it can be used more economically than steam, the latter will retain the important place which it has so long held. Batteries are made, indeed, with other elements, but somehow the zinc is the one not easy to replace, and it must be consumed, or there is no electricity generated. The negative element may be silver, copper, gold, platinum, coke, carbon, and, possibly, many other substances, but the zinc still remains as the positive element.

A number of magnets are arranged round the periphery of a wheel, disc, or cylinder turning upon an axle, and around these are ranged a succession of keepers, permanent magnets or otherwise. Each of the magnets on the cylinder is therefore tolerably close to its keepers at any moment, so that as soon as the battery power is made to act upon the electro magnets, attraction takes place. Just as the magnet and keeper are on the point of contact, or exactly opposite to each other, connection is broken for a moment, so that the impetus is allowed to carry the wheel round towards the next set of keepers, on approach to which the power is again brought into action and the wheel pulled a little farther round. In principle the action is simple, but when it is worked out in detail it has not given quite such satisfactory results as might have been expected. This is, nevertheless, of necessity the principle of all motive engines actuated by electrical agency, and very large sums are constantly expended in the attempt to produce in this manner a really satisfactory machine, that may be used for railway and other purposes.

We can construct a toy motor as follows: Arrange four, six, or as many electro magnets as can be managed, round a horizontal axis, and these, being in succession connected with the terminals of the battery, must attract or be attracted by one or more fixed magnets or pieces of steel arranged as armatures. I will now give details of one such toy, from which it will not be difficult to devise others; but before describing it it will be as well to remark here that the wire of the electro magnet and its coil, however well covered, is not always so perfectly insulated as to prevent electricity from passing sideways from coil to coil, or from some one coil of the first layer to the magnet itself. Hence, care taken in the perfect insulation is always sure to be well repaid. Do not, therefore, wind the first coil directly upon the soft iron core, but insert the latter through the hole of a bobbin made like a cotton reel with big ends, or put on a cylinder of card, and wind outside it, and if the work is important, roll round each coil a strip of thin sheet gutta percha, or coat it with paraffin wax. Use wire of 16 or 20 gauge, and lay on about four coils, one over the other, but leave out the ends, as you will need to use them.

For the machine or toy under consideration, the electro magnets need not be over two inches long. They will be of soft iron, the size of a cedar pencil, and, for a mere toy, we need use no bobbins, but just wind round a fold of bladder or paper cut in a strip and wound in a coil. We will wind four layers on each, and set five of them round an axis of box or other wood. The best way is to turn down a bit of each about ¼in. long, and cut a screw on it, or make the magnets of wood screws, which will do very well, as the iron is soft, and, being pointed, we can readily screw them into a wooden axle, like so many spokes of a wheel. For the purpose of getting more power, we can, if we like, make two sets of such spokes, but one will do for a toy. The axle is made of wood, but it has a cap of brass upon the end, the use of which is to enable metallic contact to be made with the battery, each magnet being alternately acted upon. This arrangement is called the commutator, or break, because the current is thereby alternately sent through the magnets and cut off again. There are other ways of making this part, but I give that which appears to me the most simple and efficient.

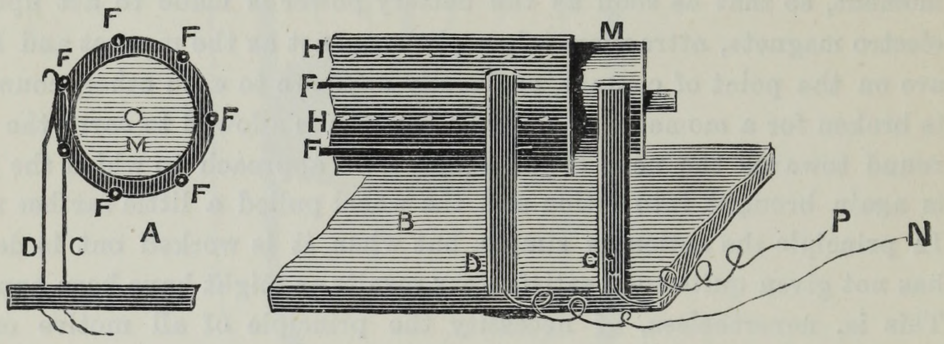


Fig. 121.—Coil, Axle, &c., showing Means of Making and Interrupting Communication.

It will be readily understood that on each coil there must be two ends of wire, and that, in order to send a current through the coil, one end must be in metallic communication with the zinc or positive element of the battery, and the other with the copper or negative terminal. Now, if Fig. 121 (A B) is inspected, we shall see how this communication is made and broken as the axle revolves. Let P N be the two battery wires; these are soldered to D C, which are two strips of hammered brass rising from the stand of the instrument. F and H are the two ends of the wire surrounding one of the magnets. Of these, one is sunk into the axle by laying it in a groove in the wood, but its end, scraped clean and freed from its cotton covering, is in metallic contact with M, the metal cap of the axle. F, the other end of the wire, stands above the surface, and is scraped bright, and is in contact with the spring (D). Whenever, therefore, the revolution of the axle brings D and F into contact, a current of electricity will pass from the zinc of the battery through the coil and back to the copper, the circuit being complete; but when by its revolution the axis carries F away from the spring (D), the latter falls on the wood of the axle, which is a non-conductor of electricity, and the circuit is broken, and the soft iron core of the coil ceases to be magnetic. All the wires have one of their ends connected to the metal cap and the other lying above the surface, the end only being bent down and inserted in a hole in the wood to keep it secure.

Then the spring which lies in contact with the projecting wires passes over the sunken ones, and these may be further protected by a coating of sealing-wax varnish. Where contact is intended to take place, both wires should be coated with mercury, or amalgamated, as it is called, to prevent corrosion, and, as I have also spoken of amalgamating the zinc of the battery, I will now describe the process, because it is of common occurrence in galvanic apparatus. The zincs are washed clean, and then wiped over with a little dilute sulphuric acid and fluid mercury, which may be placed in a dish and the zinc held in the same while it is being wiped over with a bit of tow; or the zinc may be laid flat in the dish in the mercury and acid and wiped in this way until a bright coating is spread over the surface. The sulphuric acid of the battery will act but very slightly upon zinc thus protected until the wires are connected, so that waste of the metal is to a great extent prevented. When a single cell is not powerful enough to drive a machine, two or more can be connected, uniting the zinc of one to the copper of the next by a bit of wire. The terminals of a Daniell generally end in brass knobs with binding screws for the purpose, but it will be equally effectual, and often more so, to twist together an inch or two of the wire to be joined. Flat copper bands are also excellent terminals, especially if amalgamated.

In the sketch (Fig. 122, p. 262,) of the electro-motive engine which I have been describing, the support of the revolving cylinder and the commutators are not shown, but will be understood from the drawing in connection with the previous figure. Here A is a circle or ring of wood, supporting at equal distances short bars of steel, preferably magnets, marked C. This is fixed to a base and stand (F). D is the capped end of the revolving cylinder E, into which, as explained, radiating electro magnets (B) are fixed. The wires from the coils, here made with wooden bobbins, are carried as shown in the previous figure, so as to bring the magnets alternately into action. When, however, there are a number of these, it is easy so to arrange the commutators as to cause electricity to affect two, four, or all six, as may be desired, so that they shall be attracted by the fixed magnets (C). But matters must also be so arranged that the electric action shall cease the moment the fixed and rotary magnets are opposite each other, to permit the motion to be carried on by impetus alone until each magnet again comes within attractive reach of the fixed magnet. Now, if we add to the single circle

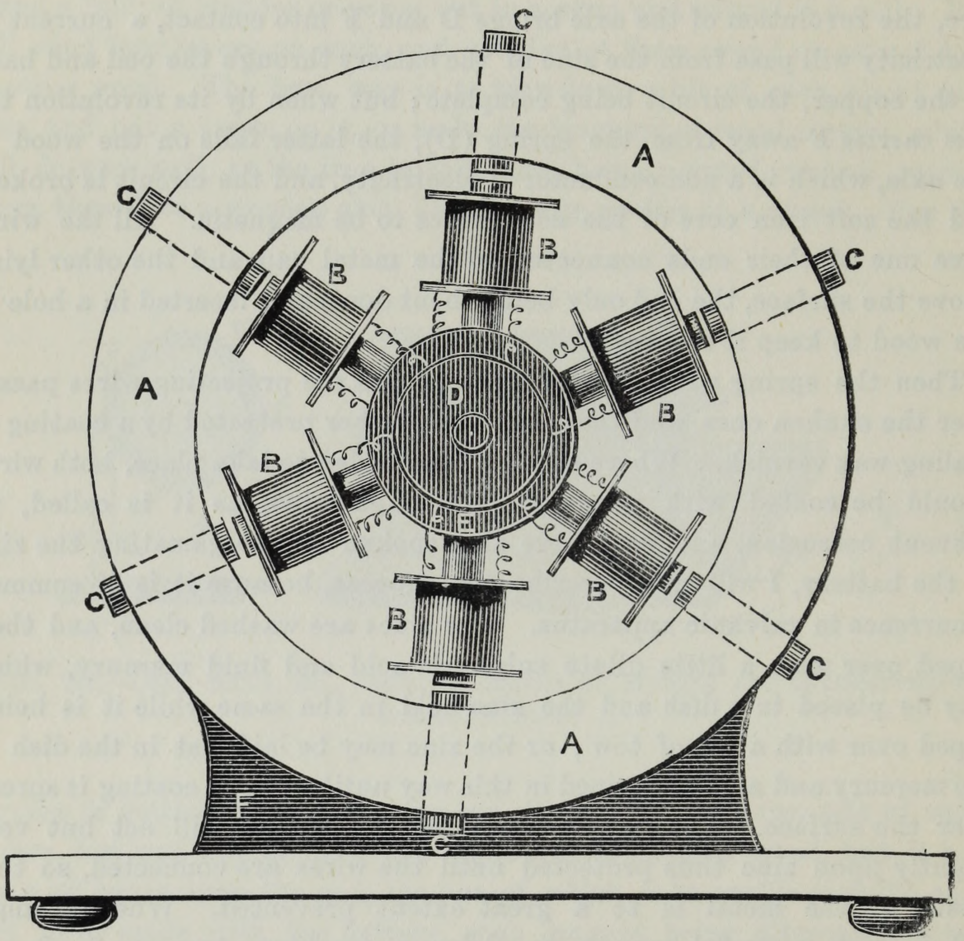


FIG. 122.—ELECTRO-MOTIVE ENGINE.

of magnets two or three others on the same axis, and set circles of fixed magnets intermediate to the first, we can obtain a continuous power, the magnets being placed so as to form a spiral like the thread of a large screw. In this way, far greater power is obtained, since every magnet may be so placed as to be almost close to the fixed one, upon which it is momentarily to act. In every case, however, the power so obtained fails to become an economical one; otherwise it is so manageable and generally advantageous that it is no wonder our engineers are constantly recurring to it as a motive power. There is not one which is so promising, yet so tantalising.

CHAPTER XXVII.

TOYS WORKED BY ELECTRICITY.—BELLS.

THERE are few persons who have not at various times and places been annoyed by inefficiently hung bells, and there are not many houses in which one or more are not defective. However well arranged at first, rust very soon obstructs the freedom of their action, or paper-hangers and painters and whitewashers one and all cause the cranks to stick fast or the wires to corrode and break. None of these drawbacks attend the use of electric bells, because the wires and their supports have not to move at all, but simply to convey the electric current from the battery to the magnetic arrangement, by which the hammer or clapper is made to act upon the bell. The latter may thus be placed at any distance from the bell pull or "push," and the wire can be carried round corners and bent about in any direction without detriment to the ringing powers of the apparatus—an advantage of itself sufficient to recommend the system for general use. Nevertheless, so wedded is John Bull to old contrivances, that the electric bell is but slowly supplanting the old and imperfect arrangement. Perhaps, like many other scientific appliances, the electric bell is generally considered a mere toy, not of very much use for practical purposes. This is quite a mistake, but the idea being exactly suited to the subject of the present book, we will call it a toy, and as such describe it.

There are two forms of electric bells in use. In one the bell makes but one stroke on pushing in the handle; in the other it continues to ring like the alarum of a clock as long as the hand of the operator presses in the handle or push which connects it with the battery. A third arrangement is sometimes used, in which the operator cannot himself stop the ringing after once setting it in action, and it is then thrown out of action by the servant or other attendant who answers the signal. Only one bell is required for several rooms, and there is an indicator in the circuit, which acts upon a sort of telegraph, and causes a disc to display a certain letter or number to indicate the particular room from which the signal has been made. Here is another advantage over the old system, in which each room has its own particular bell, with its connecting wire, cranks, and other fittings, all costing money, and all liable to injury by rust or breakage. The only question that really arises is, whether the battery can be relied on as the source of power; and in practice this has been favourably answered where the Leclanché carbon cell is used. But, permanency not being, as a rule, a characteristic of toys, we can experiment with the Daniell battery, which will serve the purpose very well indeed.

The electric bell is made to act by the magnetisation of a bar or horseshoe of iron like that previously described, a coil of covered copper wire conveying the current of electricity from the battery to the magnet. The hammer which strikes the bell is attached to, or itself forms, the keeper, and its sudden attraction, when the current passes, causes it to give the blow. Fig. 123, p. 266, will sufficiently explain such a bell, and will be found to represent one of a very simple form, easy to construct. It is a single stroke bell, *i.e.*, one blow is given each time the key is depressed by the person sending the signal. A is the bell, which can be bought for a shilling at any clock maker's. It is mounted upon a short and stout wire driven firmly into the wooden board forming the support of the apparatus. Its edge need but just clear the board, so as to allow it to sound freely. B is the hammer attached to C, a steel or hammered brass spring, fastened by the screw D, so that the hammer is about ½in. from the bell at E—the middle of the spring is riveted—an armature (E) just clearing the poles of the horseshoe magnet (F). This is also fixed to the board by a strap over its bent part, or by a holding down clamp of any other kind. I have already described this kind of magnet, and need only observe that the soft iron should be fitted with brass bobbins, and wound with eight or ten layers of cotton-covered wire, number 25 or 26, or thicker if preferred. The horseshoe may be of iron of ⅜in. thick and 3in. long in each leg, and bent so as to bring the poles ¾in. apart. The keeper, like the magnet, is to be made of a short, flat bit of soft iron, as steel, if used, will become permanently magnetic, and the object in this case is to prevent any trace of magnetism as soon as the connection with the battery is broken.

In winding the bobbins, it is essential to keep the coils in the same direction upon both, and here a mistake is easily made, for the direction is shown at R S, which at first sight looks wrong; but wind a coil upon a bit of stick, break it in half, and turn the two pieces up on end, like

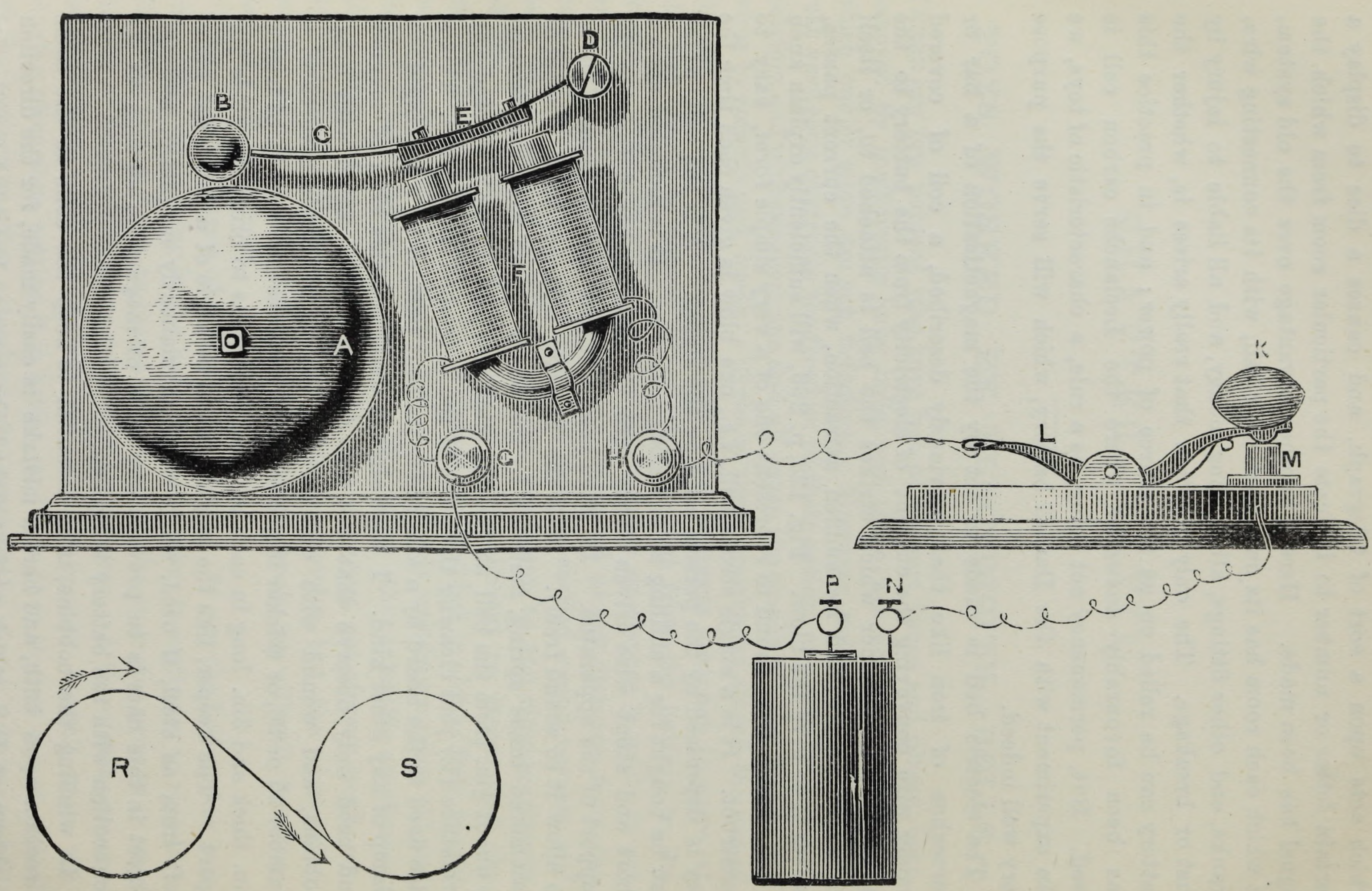


FIG. 123.—SINGLE STROKE ELECTRIC BELL.

the legs of the horseshoe, and the wire or string will be seen to take the direction here illustrated. Let the ends be ultimately brought to two binding screws (G H), or twisted round two screws of ordinary form. From one of these a covered copper wire goes straight to one pole of the battery.

We have now to turn our attention to K L. This is one form of "push" or "touch," by which the magnet is put in connection with the battery, but it may be varied in any convenient way to suit a particular case. L is a lever of brass turning upon a pivot or axle. It is bent up at each end, and to one of these ends is attached the wire leading to the magnet; at the other end is screwed a knob (K) of porcelain or wood, but care is taken that there shall be metal underneath to touch the pin or stud (M), also of metal, when the knob is depressed by the hand. When not depressed it is held free of the stud by a spring underneath it. We can now see exactly by what means the bell is rung. When the handle is pressed down it will be observed that the connection with the battery and electro magnet is complete. The current flowing from P passes to the binding screw (G), thence to the coil from which it emerges at K, thence, passing to the metallic lever (L), it proceeds by the stud (M) to the second wire attached to the other pole of the battery. As the circuit is thus complete the horseshoe becomes a temporary magnet, and attracting the keeper (E), this is brought down quickly, causing the hammer to make a stroke upon the bell; as soon as the hand is again lifted from off the knob (K) the circuit is broken, the horseshoe ceases to be a magnet, and the bell hammer again flies up to its original position over the edge of the bell. However rapidly the knob is again and again depressed the magnet will answer so that the bell may be made to keep up a peal or only caused to utter a single sound.

In practice with a powerful battery it suffices to have one wire the same as now used for conveying telegraphic messages, but two will be far better in a toy or model. No. 16 covered wire is about the best to use, and a battery of two of Daniell's quart cells will provide sufficient electricity to ring from the top of the house to the bottom. To make a bell that will continue to ring as long as the hand is steadily pressing down the touch, it is only necessary to make the hammer spring a part of the circuit. A stud is placed at E, behind the spring, against which it rests, and from this stud one of the wires goes to the battery; the other wire is led to D, the push being, of course, in the circuit as before. In this case, as soon as the magnet attracts its keeper—giving also a stroke upon the bell—the keeper being drawn away from the stud behind, it causes the circuit to be broken; it then flies back again against the stud, which, instantly renewing communication with the battery, causes attraction to take place again, with the same result of instantly breaking the circuit. This goes on with lightning rapidity, so that the strokes upon the bell are renewed instantaneously, the hand remaining steadily upon the touch. It is quite as easy to arrange matters thus as to make a bell to give but a single sound.

All connections which are made and broken by simple contact of the metallic terminals require close attention. They should always be made by means of amalgamated copper or small discs of platinum soldered on. If there be rust or dirt at any one such point the circuit will be rendered incomplete. This would be the case with the top of the stud (M) and the metallic termination of K. It will, of course, be necessary to strip off the cotton covering of the copper wire where it passes the binding screws, and here again the screws as well as wire should be amalgamated with mercury.

At Fig. 124 is illustrated a different form of push to that previously described, in order to show the variation that may be made in this part of the apparatus. It consists of a bent lever of brass, with a handle or knob of porcelain at one end for the finger and thumb. It turns upon a central screw, to which one wire of the battery is connected. The battery wire goes from F to the stud H, to which one end of the wire from the magnet is also fastened. The other wire from H on the bell board comes to the other stud, marked G. If the handle of the push is moved to the left till it touches the stud L, the other end of the bent lever then resting against G, the current will pass from one pole of the battery by the studs and bent lever to G, thence to H, and along the hammer-spring to the stud (C). It will then go to the magnet, and by its coils and line wire to H, and finally to F, the opposite pole of the battery. The connection being complete, and the horseshoe magnet drawing down its keeper and making a stroke on the bell, connection will be instantly broken between the keeper and the stud (C), and the former will fly back to the stud owing to the cessation of magnetic attraction, then at once renewing the circuit and causing the same effect as before. The stud on the opposite side of the push handle is merely a stop for the lever to rest against.

The indicator, which allows of one bell being used for several rooms, is in itself a very simple affair, which is illustrated in Fig. 125, p. 270. A mahogany box contains a set of small electro magnets, which are connected each with the line wire of a particular room, and are thus brought into the circuit between the touch of that room and the electric bell common to all the rooms. To the keeper is attached a slide carrying a tablet or disc, which is seen through a hole in the front of the case when the keeper draws it down, but is out of sight otherwise. As soon as the touch is depressed or moved, so as to complete the circuit, the tablet is then displayed at the instant that the bell also sounds. A (Fig. 125) shows the case, and B the internal arrangement; *a* the small magnet, *b* its keeper, to which is attached a wire with the slide and disc (*c*). When the attendant notices the signal, he raises the slide and keeper by means of the button *d*, until it is stopped by a stud or studs, which prevent its being raised too far and taken out of reach of the attraction of the magnet. One disc only is needed if but two rooms are to be signalled, but, with several, one case is used fitted with a row of the small magnets, each having its own shutter, so that a servant can at once see from which of the rooms the signal was sent. Although the continuously sounding bell is in one sense the more effective of the two, yet the single stroke has this one advantage—that signals can be arranged so easily. One stroke, for instance, may summon the footman, two the housemaid, or, in an office, the different clerks; and such a code can, of course, be indefinitely

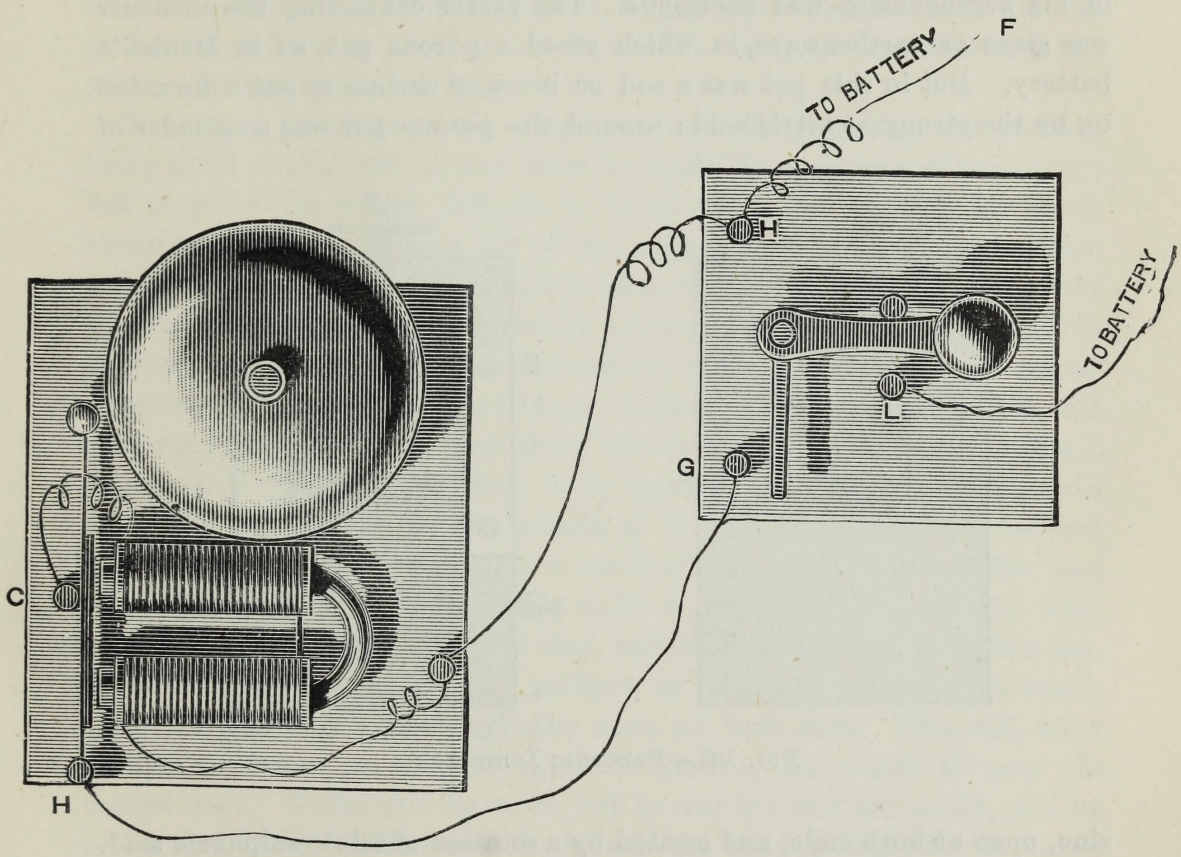


FIG. 124.—ALARUM ELECTRIC BELL WITH CONTINUOUS ACTION.

extended to suit the special requirements of the establishment in which the system of electric bells is used.

I have not said a great deal about the electric or galvanic battery because the best form for electric bells is not one which the toymaker is likely to make for his own use. But I may as well, perhaps, explain here the nature of the carbon battery that has now very generally taken the place of the Daniell cells. I believe Bunsen's was the first battery with coke instead of copper or silver as the negative element, and the power of his arrangement was enormous. The vessel containing the elements was glass or earthenware, in which stood a porous pot, as in Daniell's battery. But in this pot was a rod or block of carbon or gas coke acted on by the strongest nitric acid; around the porous pot was a cylinder of zinc, open at both ends, and excited by a solution of dilute sulphuric acid. The fault of this battery is that the fumes given off from the coke and nitric acid are so deleterious and suffocating that the actual battery must stand out of doors or under a chimney or special air shaft. Grove's battery, in which the carbon is replaced by a plate of platinum, the same acids being used, presents a similar disadvantage, but is also of great power, and very suitable for the performance of brilliant experiments when persistent and long-sustained action is not specially required. But for telegraphy and bell ringing we require a power not necessarily very great but well sustained—a power that shall go on for weeks or months without special attention. One or two batteries possess this qualification in an eminent degree. The bichromate battery is Bunsen's arrangement,

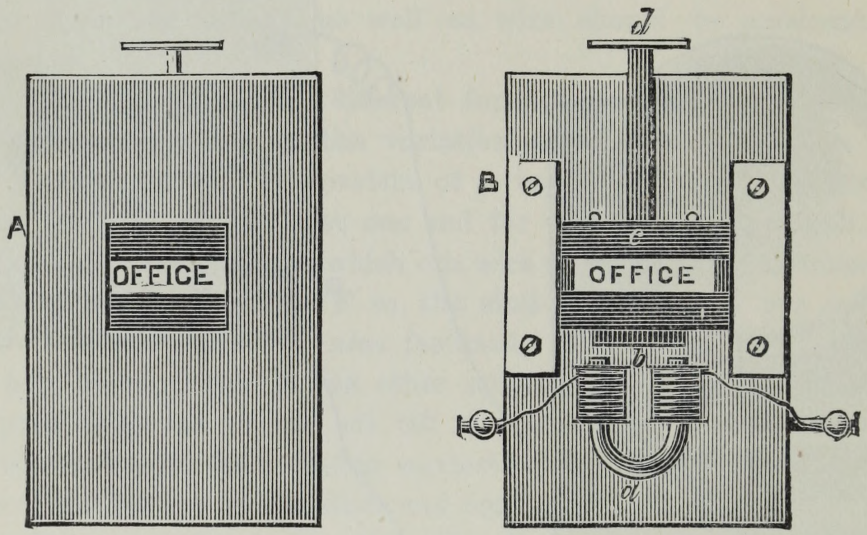


Fig. 125.—Electric Indicator.

but with bichromate of potash around the carbon, acidified with sulphuric acid. This is a constant battery much liked by many.

Another form is made by a plate of zinc between two plates of carbon, excited by bichromate of potash in a concentrated solution, with a little sulphuric acid as before. But the Leclanché cell is so good and so constant in its effects that it is fast supplanting all others. In this the carbon rod stands in a porous cell as before, but instead of an acid solution, a mixture is used of powdered coke, manganese, and carbon, and the inner cell is sealed up so as to prevent corrosion from the sal ammoniac, which is used in the form of a concentrated solution in the outer cell to act upon the zinc.

The carbon batteries at the shops are beautifully got up, the carbons being sawn neatly into square bars, or made by a process of moulding; but it is by no means difficult to make one good enough for home experiments by obtaining a bit of gas carbon or coke at the gas works, and sawing and grinding it to such a form that it can be suspended inside the porous cell. The zinc will hardly answer if cut from a sheet, owing to its thinness, as it will soon be altogether consumed by the acid or sal ammoniac. It ought to be cast to a thickness of ¼in. or thereabout, and well amalgamated. You may effect this operation of casting by using a clay mould well dried or baked, or by making use of such a thing as a drain tile and standing in the middle of it a solid cylinder of dried and baked clay large enough to allow a space of ¼in. between it and the pipe to receive the melted metal. To make a clay mould in another way, heap up a mass of well worked clay, and having flattened it at the top, press down into it a common gallipot or jam pot, mouth downwards, or, preferably, any smooth cylinder open at both ends. This will, when withdrawn, leave an annular space or groove, into which to pour the melted zinc. Take care, however, not to use the clay too moist, and on no account hold the face near it, in case the sudden formation of steam from the wet mould should drive out the molten metal, as will occasionally happen, in spite of ordinary precautions.

All parts of a battery made of metal which are liable to corrosion should be coated with some one of the varnishes sold for the purpose, or with melted paraffin (wax) poured over them. A battery so sealed and protected will often work for two years without any attention whatever, and when it ceases to act all that is necessary is to unfasten the wires and replace it by a new or freshly-charged one, a mere work of a minute or two. When removed, the worked out cell or cells must be emptied and well washed, new zinc placed in the cells, and all metal connections and screws cleaned and revarnished. It will then act again as well as ever. The carbon will not require renewal in most cases, but only to be well soaked and brushed in hot water, without using soap or soda. There is nothing difficult in the construction of this or any other form of electrical apparatus if attention be paid to the metallic connections. It matters little that home-made apparatus is of a rougher kind, and that the insulated wire may not, perhaps, be wound with perfect evenness. At the same time, as I have advised throughout the whole of this book, let every endeavour be made to attain neatness in the construction of toys, whether of a scientific kind or otherwise. They may or may not work the better for extra care in this respect, but they will, at any rate, be more creditable as well as more satisfactory to the maker.

I have now fulfilled the task which I undertook, and have carried the toymaker onward from lesser to greater and more important work, still, however, leaving him to encounter such difficulties as time and practice alone will enable him to overcome. This is, in point of fact, the difficulty inseparable from all such instruction books as the present. One is obliged to assume a proficiency and a rapid advance in constructive skill which cannot possibly take place within that imaginary period intervening between chapter and chapter—a period wholly theoretical. A toy cart or doll's house will not in reality be made to-day and an engine to-morrow by an unpractised hand, but I hope that the descriptions given may, nevertheless, stimulate the amateur carpenter and toymaker to work with patience and deliberation, as showing him how he may advance in knowledge and manipulative skill by ordinary care and painstaking. With every good wish for his success, I now, therefore, bid the toymaker farewell.

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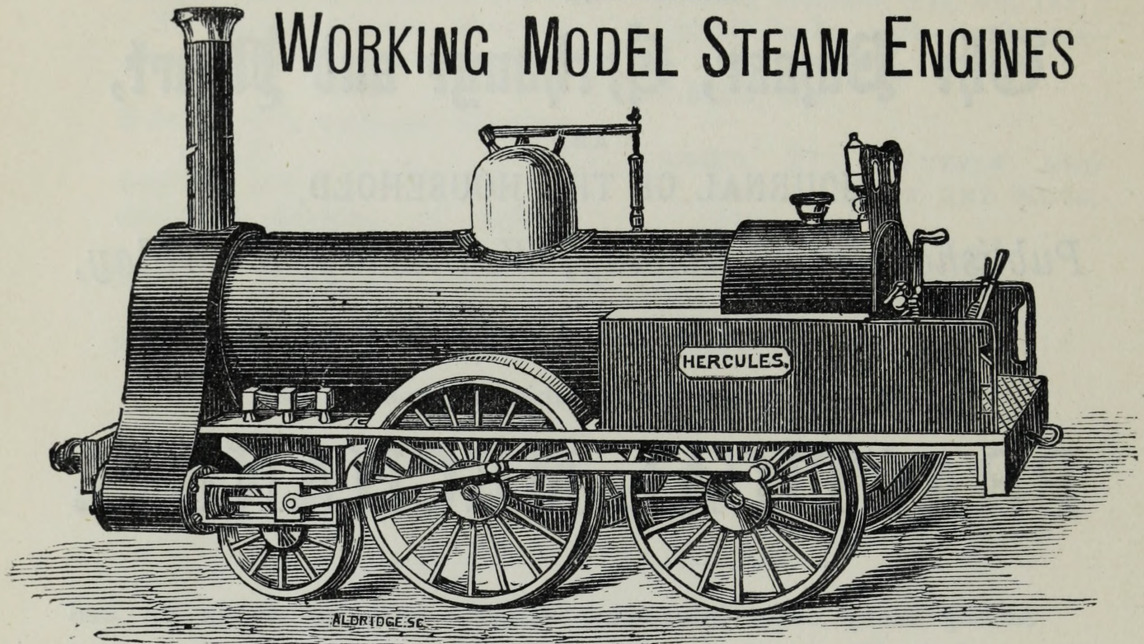

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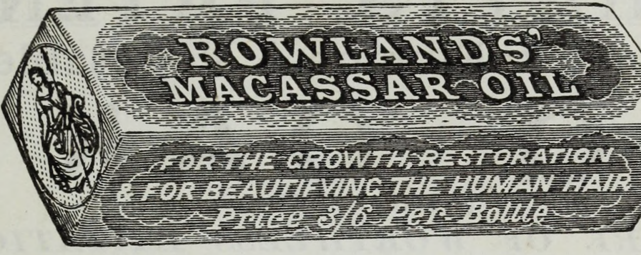

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